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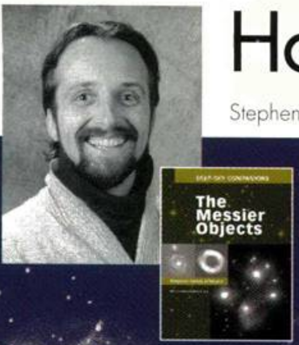

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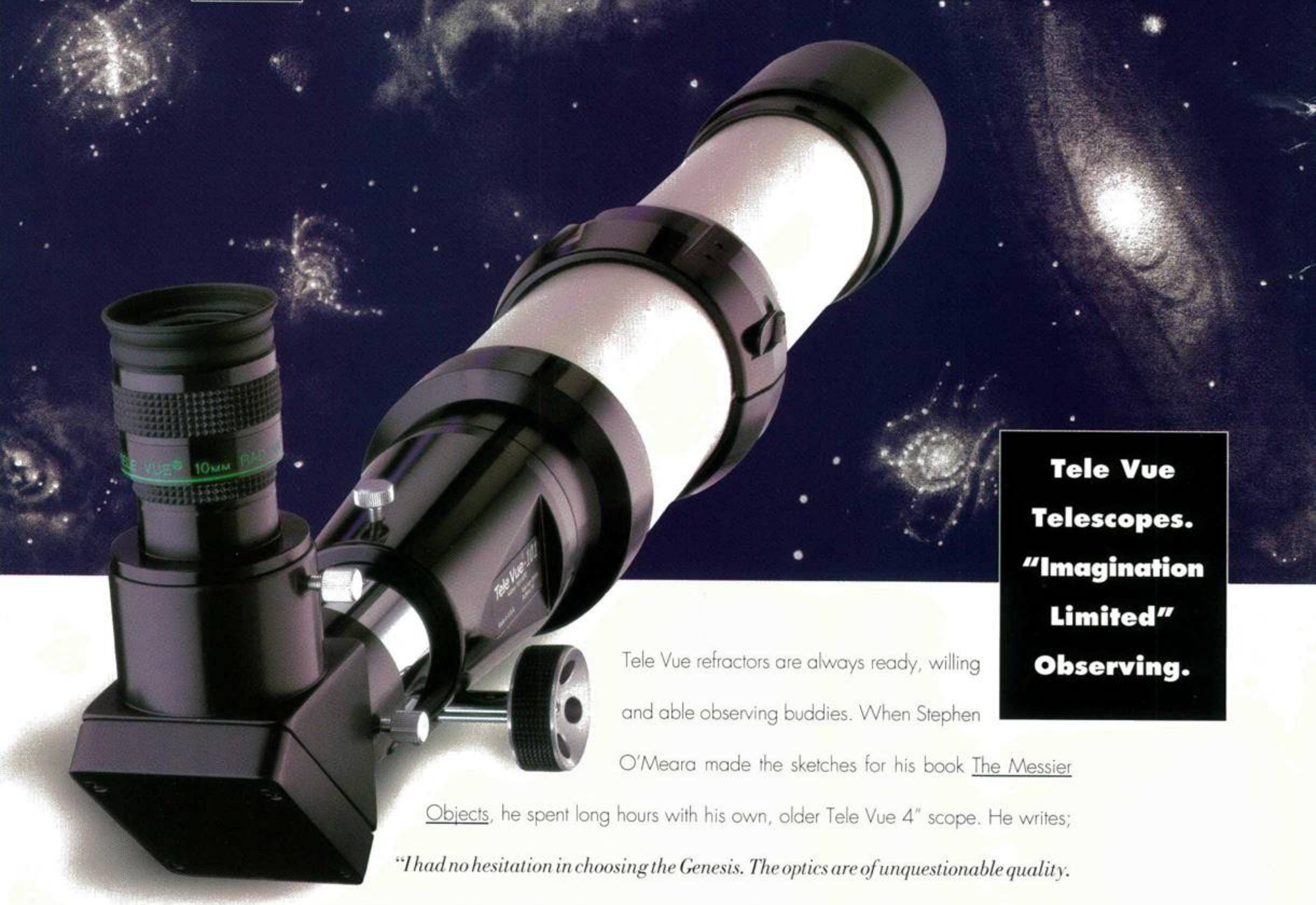
Stephen James O'Meara, author, Sky & Telescope editor and first to visually recover Halley's comet. Drawings by Stephen James O'Meara



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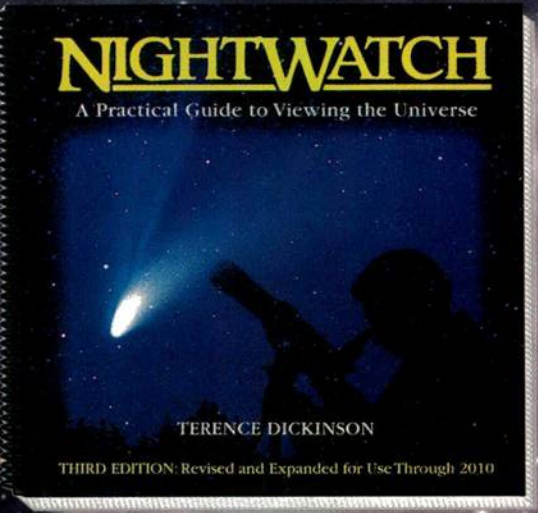
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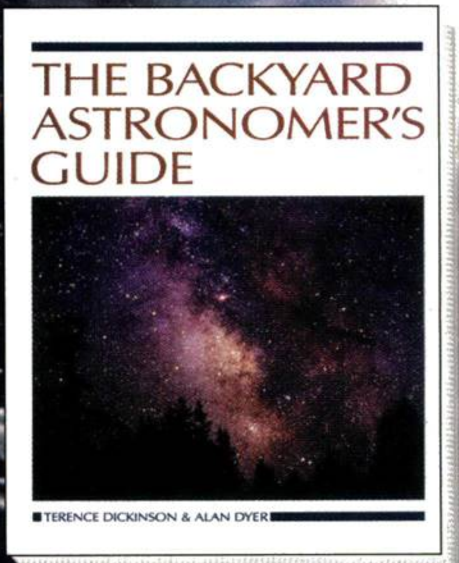
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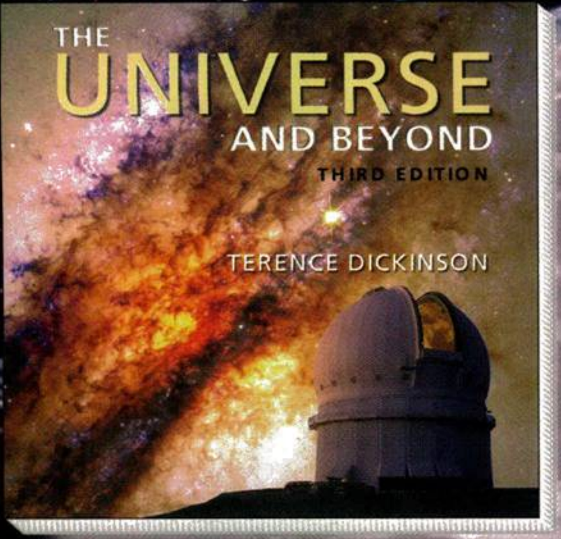
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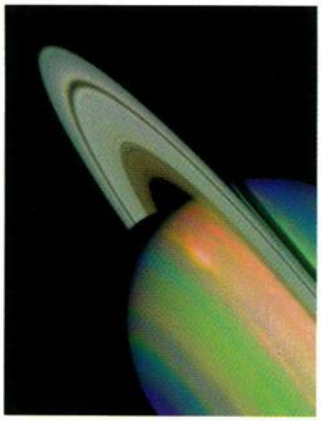

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80 Guide to Accessories

Astronomy

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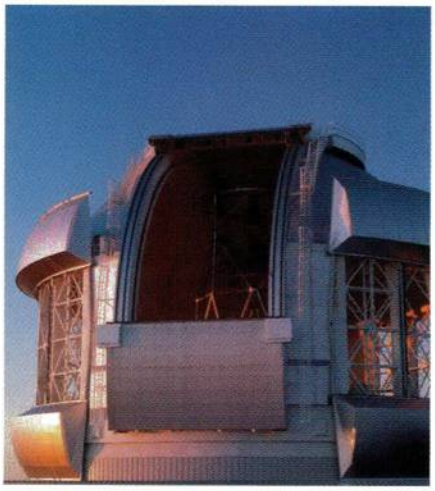

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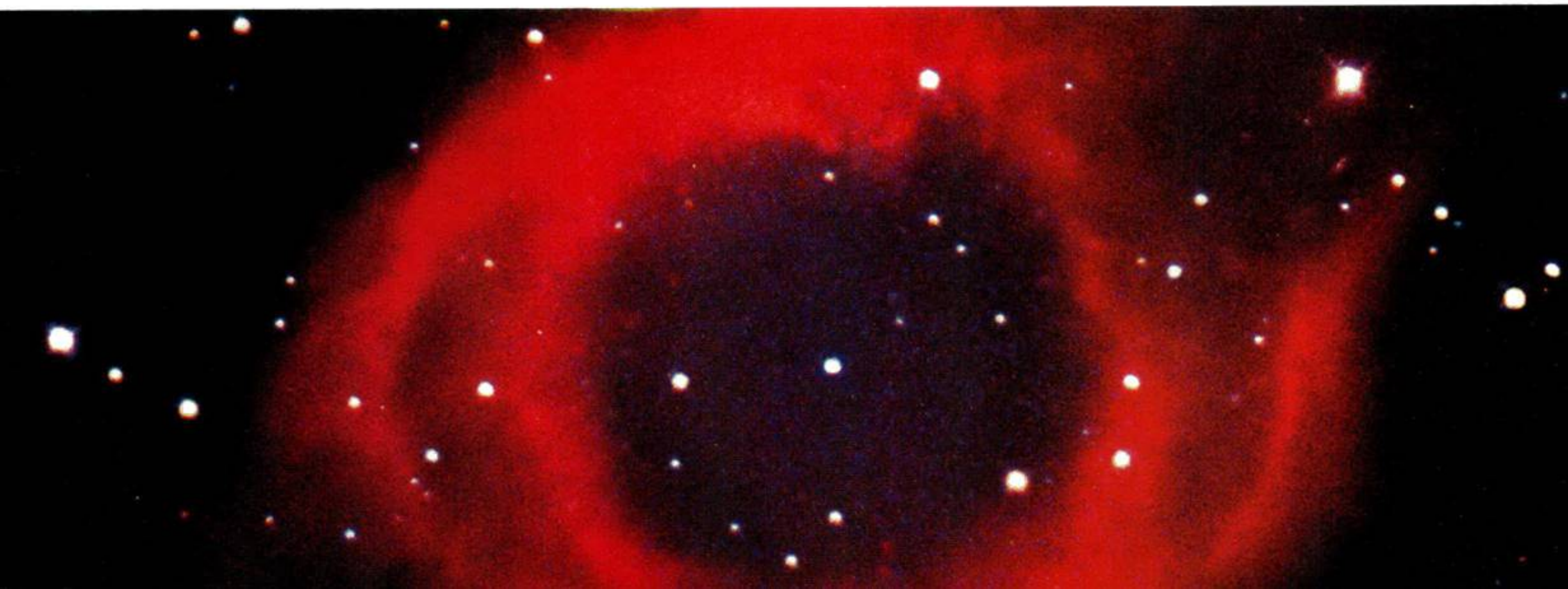

At *the* Eyepiece

The Day the Universe Changed

On a sweltering day we drove up the mountain, twisting and turning our way through the switchbacks. Gentle pine forest covered the dusty landscape and a sterling prize awaited us. After a rolling journey from the Pasadena basin below, we arrived atop Mt. Wilson and proceeded to the Snow solar telescope, enjoying splendid views of solar spectra. But to an unabashed deep-sky observer like me the real prize lay in seeing the 100-inch Hooker telescope, one of the great instruments in the history of science.

Robert Eklund/*Astronomy*

With the 100-inch Hooker telescope at Mt. Wilson.

The cavernous underbelly of the 100-inch dome is much like a mildewed museum, a throwback to decades ago when historic acts permeated its airspace. Lockers with plastic nameplates still attached mark the former personal spaces of Fritz Zwicky, Walter Baade, and, yes, Edwin Hubble. The debris of science, old dewars, antiquated computer boards, extra tanks of liquid nitrogen, and machine shop spare parts occupy spaces all over the building. It's a curious blend of past and present in a structure that can't quite decide whether it wants to remain a working observatory or slide into the mode of full-time tribute to a previous age of glory.

Only when walking upstairs did we, *Astronomy* magazine's Bonnie Gordon, Jim Slocum, Carole Ross, and me, meet the past face to face. On a level immediately below the observing floor stood the telescope's detached Newtonian focus cage, and on it the plateholder — an item now earmarked for the Smithsonian — that was used the day the universe changed. That day was October 5, 1923, when Hubble used the Hooker telescope to image a Cepheid variable star in the Andromeda Galaxy (M31). At first he believed the star was a nova and that the "spiral nebula," as M31 was then known, was a glowing cloud of gas in the as-yet undefined Milky Way. Hubble's discovery of the variable, a particular type of star of known brightness, led to the realization that the spiral nebula was incredibly farther away than previously thought, indeed that it was a whole system of countless stars in itself — an "island universe," or galaxy. Hubble's work and that of others at Mt. Wilson and around the world exploded the distance scale of the universe and defined the galaxies that inhabit it.

Though Hubble's landmark discovery occurred nearly 80 years ago, thousands of personal discoveries await you in your exploration of the universe. Our package of stories this year includes an in-depth exploration of the Andromeda Galaxy, a sweeping tour of the solar system, and a look ahead at the great telescopes of the future that will take their places alongside the Hooker in future history. What discoveries lie ahead of us no one knows, but we can be sure that if we become too settled, it probably means that the universe is about to change yet again.

Dave Eicher, Editor

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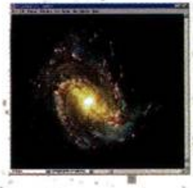

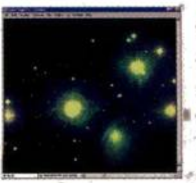

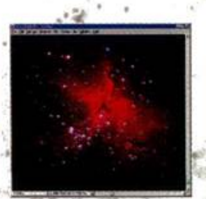

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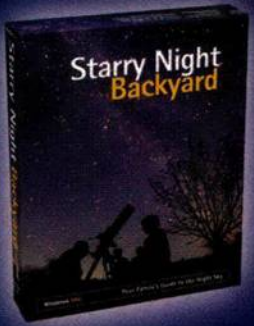

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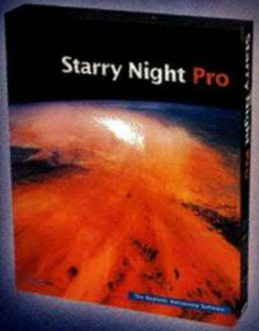

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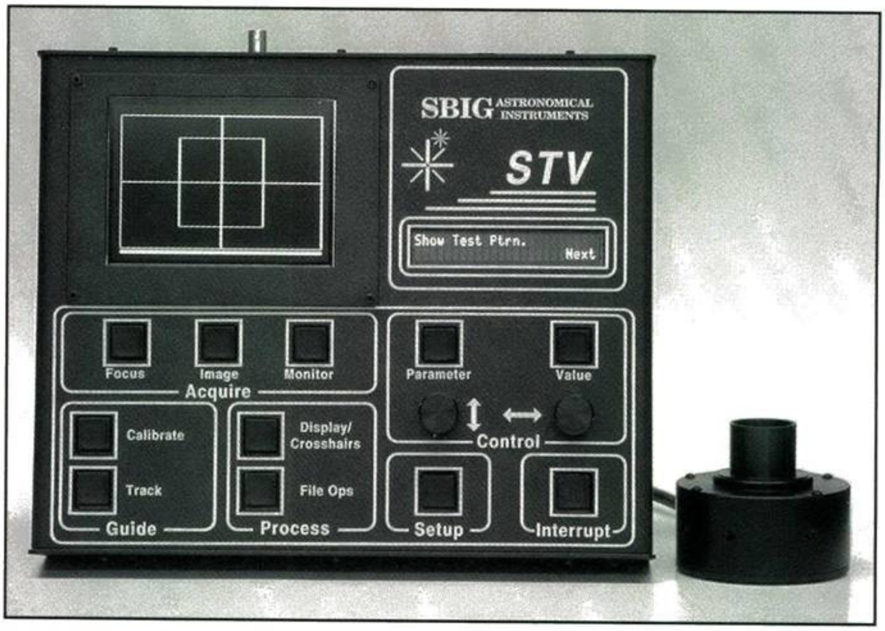
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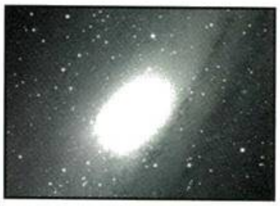

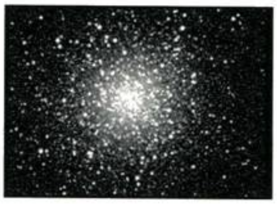

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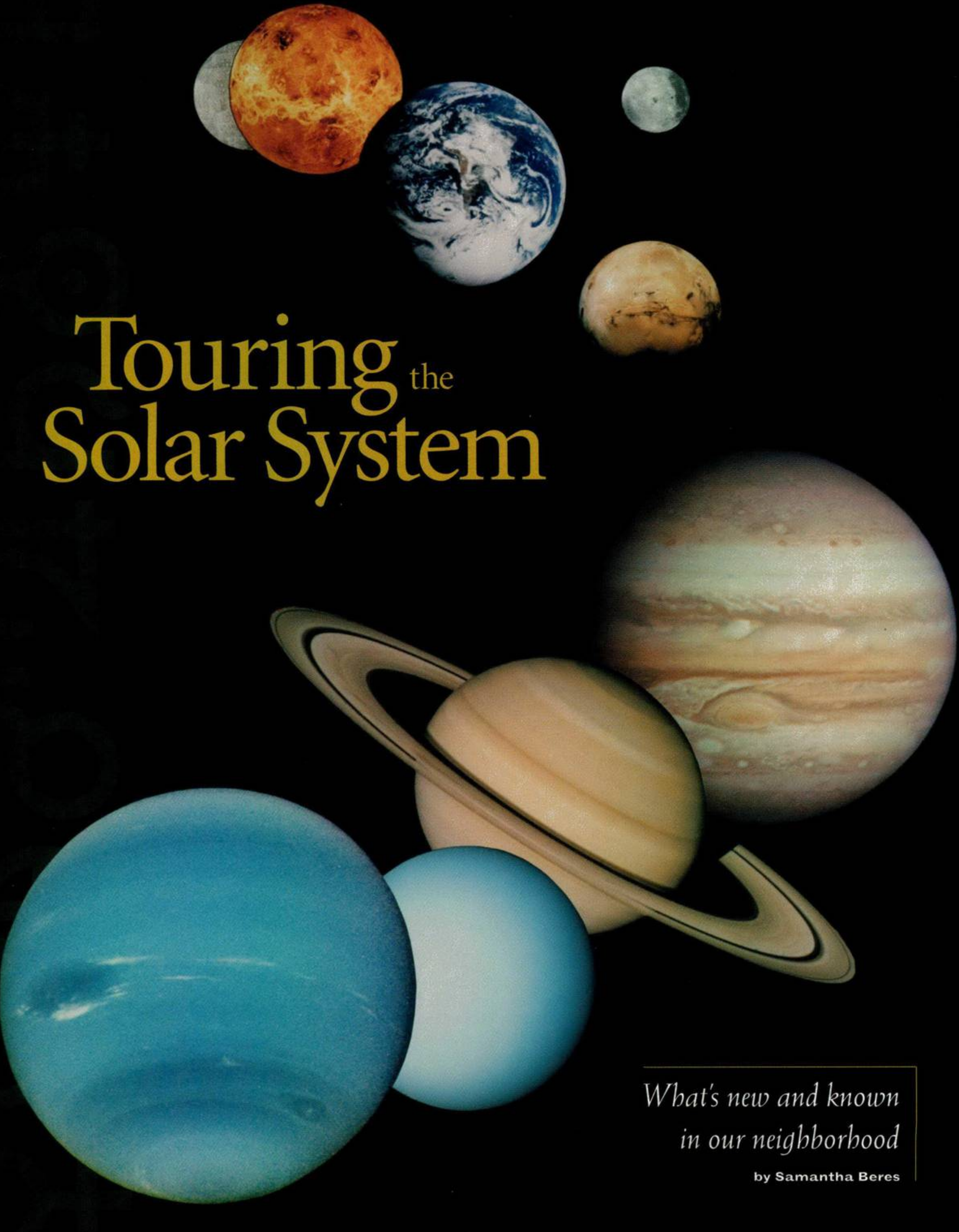


Touring the Solar System

What's new and known in our neighborhood

by Samantha Beres

Mercury

Blowing hot and cold.

Vital Statistics

Mass: 7.3 x 10^{23} lbs

Diameter: 3,032 miles

Mean density (lbs/ft^3): 339

Escape velocity:
9,600 mph

Average distance from sun:
36 million miles (0.4 AU)

Rotation period:
59 Earth days

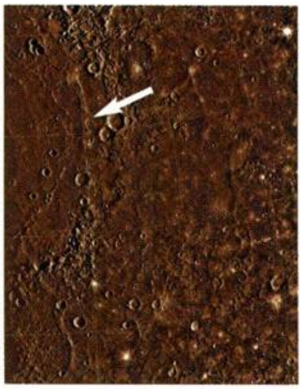
Revolution period:
88 Earth days

Maximum surface
temperature: 870° F

Minimum surface
temperature: –300° F

Atmospheric components:
trace amounts of hydrogen
and helium

The largest known surface feature on Mercury is the Caloris Basin, below, which is 840 miles in diameter.



All images courtesy of NASA/JPL unless otherwise noted

Swift, high-spirited Mercury, which orbits the sun in just 88 days, remains a stranger to us in significant ways. Though views of Mercury captured during a 1970s space mission suggested a planet with an inactive, moonlike surface, those same pictures have only recently unveiled a more dynamic history. Thanks to faster computers and sharper image-processing, a recent resurrection of data from three Mariner 10 flybys (1974–1975) reveals a surface shaped by volcanism as well as numerous impacts. Old lava flows and quake faults pepper Mercury's crust.

Mark Robinson of Northwestern University has been reanalyzing Mariner 10 images made with ultraviolet and orange filters. His team is finding that various types of boundaries between geologic formations on Mercury's surface indicate various processes at work in planet formation. "One of the controversies about Mercury was that there was no evidence of volcanoes," says Robinson. "I think I've made a pretty good case that there are volcanoes on Mercury."

Color images reveal the flow patterns of volcanic eruptions in many regions on Mercury. Lava spread to form smooth plains and rilles (channels or collapsed lava tubes) within the plains of some craters. In other areas, the images show the clear signs of impact craters.

The Mariner program, NASA's single foray to Mercury, collected pictures of only half the planet. But Earth-based radar research hints at the presence of volcanoes on other areas of Mercury. Reflections show rough terrain that is consistent with volcanic structures.

While unlocking the secrets of decades-old data might be challenging, Robinson looks forward to results from Messenger, a mission to orbit Mercury due to launch in 2004. In addition to answering more questions about surface structure and dynamism, Messenger might be able to unravel other mercurial mysteries:

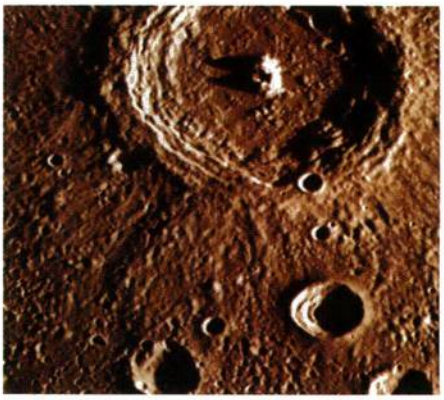
The planet's high density, second only to Earth, suggests a massive iron core which may be as large as the moon, but spectra point to iron-poor minerals at the surface. Why does a planet so rich in iron have so little in its crust?

Radar-bright spots at Mercury's poles suggest ice in nearby craters. How could ice exist on a planet so near the sun? The high density of Mercury can't be explained by current accretion models for planetary formation, so how did this planet take shape?

- Mercury is the closest planet to the sun, and on its surface a visitor could sizzle or freeze.

- Because it is so near the sun, Mercury is often hidden in the glare of our star's light.

- Mercury, which has a rotation period of 58.6 Earth days, is smaller than Saturn's moon Titan and Jupiter's moon Ganymede but larger than Pluto.



- The planet is heavily cratered, with impact scars from countless bombardments by meteoroids; it also shows evidence of volcanic activity.

- Mercury has an extremely thin helium atmosphere, and scientists have detected ice at the poles.

- Because of its fast apparent movement in the sky, early civilizations throughout the world recognized Mercury as a snappy messenger like the Roman god for whom it was named.

Venus

Our twin planet gets too hot to handle.

Vital Statistics

Mass: 1.07 x 10^{25} lbs

Diameter: 7,521 miles

Mean density (lbs/ft^3): 327

Escape velocity: 23,300 mph

Average distance from sun: 67 million miles (0.7 AU)

Rotation period: 243 Earth days (retrograde)

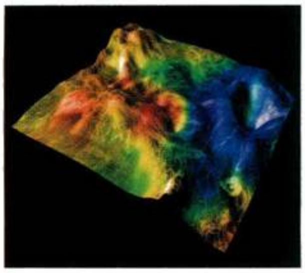
Revolution period: 225 Earth days

Mean surface temperature: 850° F

Atmospheric components: 96% carbon dioxide, 3% nitrogen, 0.01% water vapor

Surface materials: basaltic rock and altered materials

Below: Circular depressions with associated fracture patterns called "coronae" are apparently unique to the lowlands of Venus and tend to occur in linear clusters along the planet's major tectonic belts.



During the past 40 years, the major technology astronomers have used to see the surface of Venus through its thick cloud cover has been radar, a somewhat crude tool to study our sister planet. Gradual improvements in radio telescopes revealed — not unexpectedly — a surface covered with volcanoes. More surprising, though, was the realization that none of the surface features could be more than about 500 million years old, a fortnight in geologic time. Theorists suggest that volcanic eruptions have resurfaced the whole of Venus, though they can't agree as to whether this happened suddenly in one catastrophe or as part of a continuous process. The heavy weight of evidence is leaning toward a brief, catastrophic resurfacing.

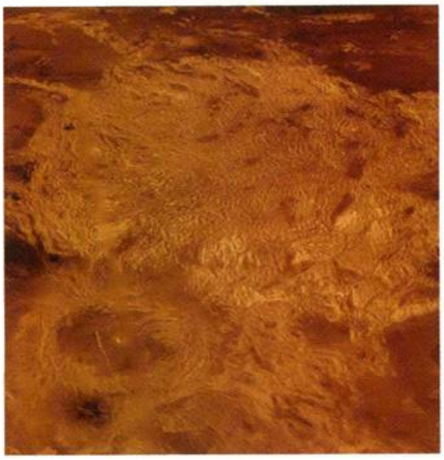
New tools are beginning to unlock more about the veiled surface of Venus and its atmosphere. Infrared Earth-based telescopes can cut through the dense clouds that surround the hottest planet in our system — but only periodically every 19 months. When Venus passes between Earth and the sun, telescopes can collect data through spectral windows in the clouds.

The dense atmosphere of Venus produces an effective greenhouse; some sunlight gets to the surface, but infrared radiation coming from the ground is trapped by gases. A blanket of thick sulfuric-acid clouds also traps heat to bring on blazing surface temperatures as high as 900° F.

The planet-wide clouds are opaque at most infrared wavelengths, but a few relatively transparent regions can be observed from Earth, allowing images of the surface. The data collected record the greenhouse gases that exist below the clouds. Data on atmospheric temperatures close to the surface and spatial variations in the cloud thickness are also collected. Add to this the results of several NASA space mission observations and a model of the greenhouse effect begins to emerge.

"Deciphering today's greenhouse effect on Venus will ultimately give insight into how greenhouse gases affect the climate of our own planet," says Vikki Meadows of the Jet Propulsion Lab "and why two planets that were probably very similar initially, evolved to become so very different."

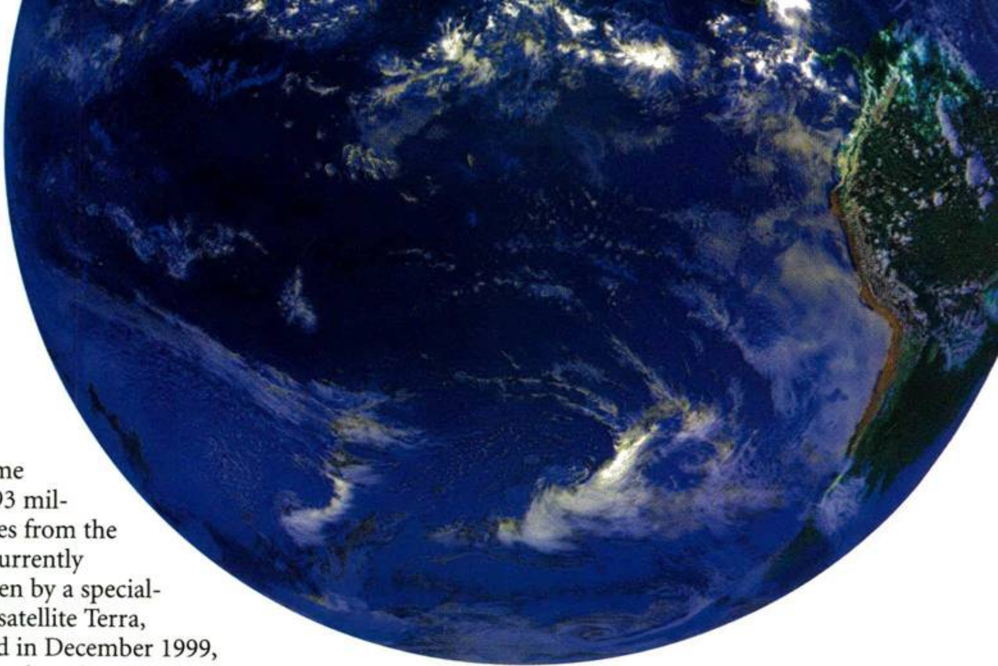
- Similar to Earth in size, Venus has a thick atmosphere of carbon dioxide and sulfuric-acid clouds. The clouds cover the entire surface of the planet, masking any surface features that might be seen in visible light.



- The immense heat and pressure at its surface make Venus hostile even to spacecraft.
- Venus was the target of several spacecraft beginning in the 1960s. The the United States sent Mariner, Pioneer Venus, Magellan, and Galileo to Venus, and the Soviet Union sent two missions.
- Magellan used radar to reveal volcanic lava flows and quake faults during four years in orbit.
- Maxwell Montes, the highest point on Venus, is more than 7 miles high.

Earth

The abode of life.
Catch it while you can.



Vital Statistics

Mass: 1.32×10^{25} lbs

Diameter: 7,926 miles

Mean density (lbs/ft^3): 344

Escape velocity:
25,000 mph

Average distance from sun:
93 million miles (1 AU)

Rotation period:
24 Earth hours

Revolution period:
365 Earth days

Mean surface temperature:
45° F

Highest point on Earth's surface: Mount Everest (which is more than 5 miles above sea level)

Atmospheric components:
78% nitrogen, 21% oxygen, 1% argon.

Surface materials:
basaltic and granitic rock and altered materials.

Below: Earthrise is captured by Apollo 11 from lunar orbit just before the spacecraft landed on the moon.

Our home planet, 93 million miles from the sun, is currently being seen by a specialist. The satellite Terra, launched in December 1999, orbits Earth and uses remote sensing to simultaneously study Earth's clouds, water vapor, small particles in the atmosphere, trace gases, and land and oceanic properties. Terra will help refine our understanding of how these things interact and affect Earth's energy and climate.

Uran Kauffman of Goddard Space Flight Center says the comprehensive study of our home planet will give Earth a major ongoing checkup to see how systems work with one another. "It's the first time we'll look at Earth from all possible aspects, as one system."

Terra is part of a 15-year-long project that will give scientists all over the world an opportunity to watch changes on Earth and to determine how the changes occur. "It's fascinating to search for conditions for life on other planets, but here we know we have life and vegetation. We need to work closer with this planet to see how we interact with it," says Kauffman.

Earth, well-studied as it is, keeps some secrets from scientists that have been more easily revealed on other planets. Erosion and continental drift have erased much of our planet's geological history. Our most elderly rocks are perhaps 4 billion years old, but most of planet Earth's exterior is 100 million years old.

Other terrestrial planets generally show more of the scars from impacts during the violent evolution of the early solar system. Earth does not. But geophysicists have discovered a great deal about Earth's origins from studying its internal structure, right to its hot, tempestuous core. Scientists extrapolate that as terrestrial planets began to grow by gathering dust particles and rocks, all were molten at the surface. As material hit Earth's molten surface, the heaviest substances dropped to the core and the lightest formed the crust.

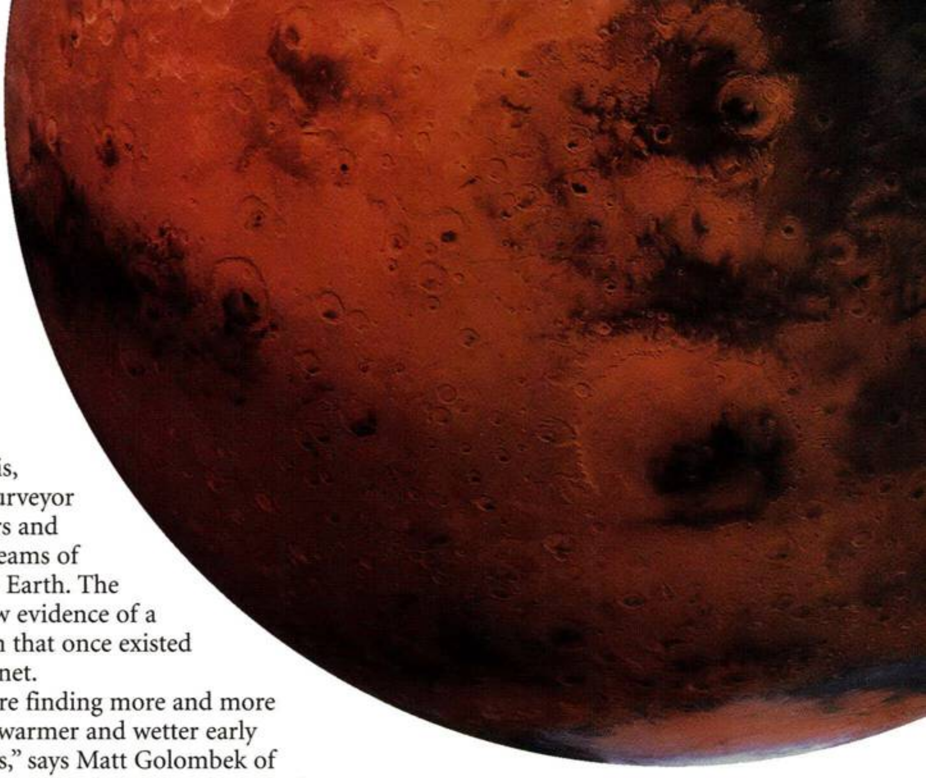
The moon seems to be a great ball of solid rock that orbits the Earth. So far it's the only place in "outer space" humans have set foot. Plenty of theories have emerged for the birth of the moon, but the most current is that it's the result of a huge impact between Earth and a much denser body. The collision tore a chunk of rock from Earth's mantle and that chunk, mixed with bits of the impacting object, became the moon.

The moon, 2,160 miles in diameter, carries a rich and decorative pattern of craters that resulted when asteroids, meteroids, and comets hit the moon. The moon's craters vary wildly in size; the largest is 1,600 miles across and the smallest is the size of a pinprick. Cratering makes the moon a great target for telescopic visits. Through a scope, you can see craters, maria (smooth lava beds), lunar highlands, rays, rilles (winding channels), and mountains.

The crust of Earth grew unstable and the continents assembled, broke apart, and reassembled. This notion of giant plates of crust that formed and now move against each other is called plate tectonics. Plate tectonics is driven by convection currents that transport heat from radioactive decay in Earth's core. Scientists recognized only in the mid-20th century that plates move around on Earth's surface, so who knows how much an orbiting satellite will find to extend our understanding of home.

Mars

Life on Mars?
A resounding maybe.



Vital Statistics

Mass: 1.42×10^{24}

Diameter: 4,222 miles

Mean density (lbs/ft^3): 246

Escape velocity:
11,200 mph

Mean distance from sun:
142 million miles (1.5 AU)

Rotation period:
1 Earth day

Revolution period:
687 Earth days

Maximum surface
temperature: 98° F

Minimum surface
temperature: –190° F

Highest point on surface:
Olympus Mons

Atmospheric components:
95% carbon dioxide,
3% nitrogen,1.6% argon

Is there life on Mars? Some researchers argue that the martian meteorite found on Earth, below, contains a once-vital creature.

As you read this, Mars Global Surveyor is orbiting Mars and sending back reams of information to Earth. The latest data show evidence of a northern ocean that once existed on the Red Planet.

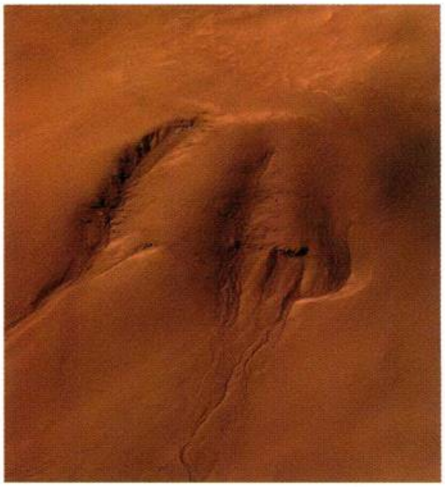
"I think we're finding more and more evidence for a warmer and wetter early period on Mars," says Matt Golombek of the Jet Propulsion Lab. "There's a fair bit of evidence from the topography data that there were basins filled with water that spilled over to larger areas and that most of the drainage was going downslope — all very suggestive that an ocean filled the northern plains at some point."

In addition, mapping shows what appear to be strandlines; on Earth strandlines are the beaches after the water has receded. Many of the strandlines appear to be at constant elevations, a consequence of liquid water sitting on a planet. Since liquid water is a key for life as we know it, learning the history of water on Mars will help scientists determine if life in any form could have commenced there.

Human fascination with Mars has always depended somewhat on the hope that life resides there. Until the powerful telescopes of the mid-20th century emerged, some observers believed they saw signs of civilization in the linear markings on the martian surface. In the 1960s NASA Mariner flybys imaged an apparently lifeless, moonlike surface. Then in 1971, NASA put Mariner 9 into orbit around Mars when the planet was encased in a giant dust storm. By 1972, the storm ended, the dust cleared, and Mariner 9 began its complete study of Mars. Later other craft delivered landers to the surface and the landers sent back no signs of life. During the 1990s, martian meteorites, the Mars Pathfinder mission and its famed rover, and Mars Global Surveyor began to refine our search for water on the Red Planet. Newly released images reveal that water has emerged from below the martian surface to leave its mark in recent time.

- The martian environment is so appealing to researchers because of all the planets it seems the most like Earth.

- It seems certain that Mars once had flowing water, but new revelations suggest there may still be water at some locations on the surface of the Red Planet.

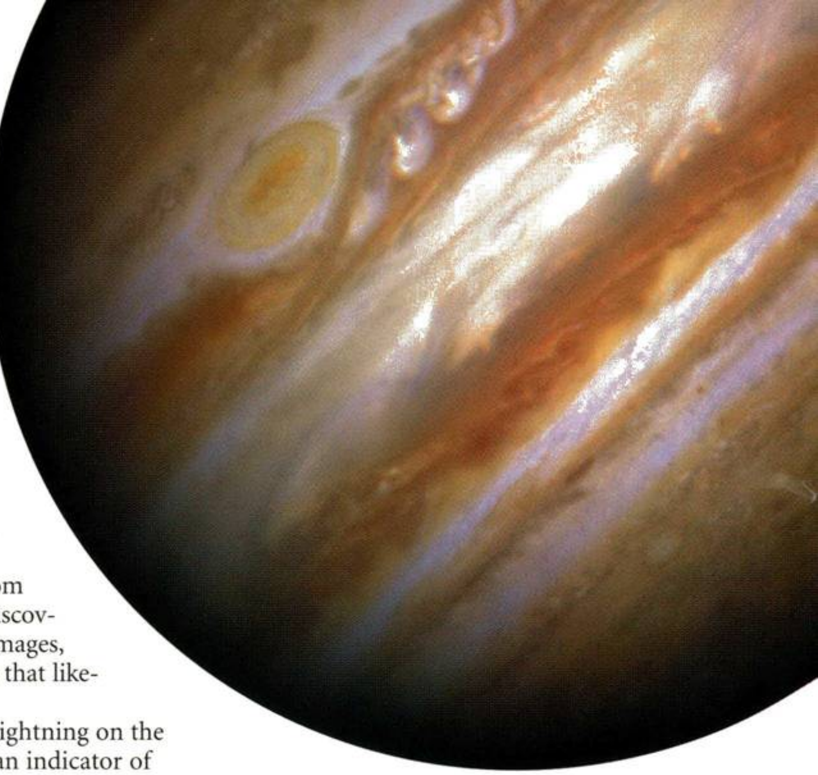


- Mars is very cold now with a thin atmosphere by Earth standards, but it seems certain that the martian surface once had a warmer climate.

- Mars Pathfinder landed on the planet on July 4, 1997, delivering a mobile robot rover called Sojourner that explored its immediate vicinity. Like earlier landers it found no evidence of life.

Jupiter

The best bet in our system for a stormy afternoon.



Vital Statistics

Mass: 4.19 x 10^{27} lbs

Diameter: 88,846 miles

Mean density (lbs/ft^3): 83

Escape velocity:
133,100 mph

Average distance from sun:
483 million miles (5.2 AU)

Rotation period:
10 Earth hours

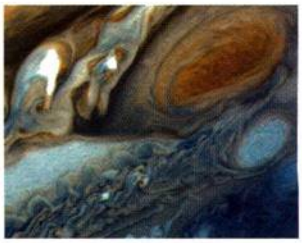
Revolution period:
12 Earth years

Mean surface temperature:
–244° F (cloud tops)

Atmospheric components:
86% hydrogen, 14% helium,
0.2% methane

Rings: Faint ring.
Infrared spectra suggest it contains rock fragments.

Jupiter's famed Great Red Spot, below, is visible through a small telescope. It marks a storm that has been raging for hundreds of years. Such energetic storms form in cloud bands high in Jupiter's massive atmosphere.



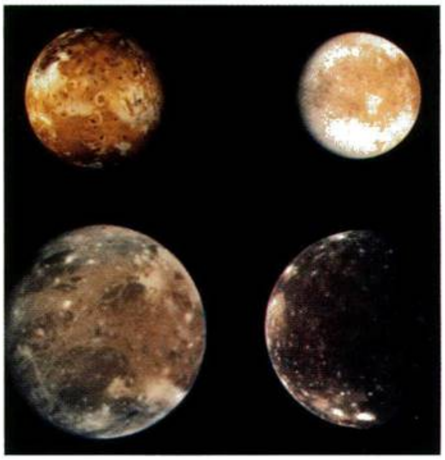
Weather on Jupiter could be compared to a food chain. At the top, enormous storms and winds feed on energy from eddies below. A recent discovery, revealed in Galileo images, points to thunderstorms that likewise drive the eddies.

"Voyager showed us lightning on the night side of Jupiter — an indicator of powerful updrafts and release of latent heat that supply energy for the eddies, but we couldn't link it up with the day side," says Andrew Ingersoll of Caltech. Galileo pictures portray a day side with the familiar cloud features of a thunderstorm, then a couple of hours later, the night side of the same territory with flashes of lightning. In effect, the images link the lightning to its source.

"It is a reverse cascade of energy from small scales to large scales," says Ingersoll. On a large scale, he is referring to weather such as the Great Red Spot, a storm that has thrived on Jupiter for at least 300 years, and jet streams that move up to 400 miles per hour. The discovery of these thunderstorms should help scientists build more precise numerical models of the weather patterns on Jupiter.

Below the thunderstorms, Jupiter has no solid surface. Like the other giant gas planets, Saturn, Uranus, and Neptune, Jupiter is liquid because the elements that form it won't condense at solar system temperatures. Giant cloud bands stripe the planet latitudinally and are especially obvious near its equator. The cloud bands are defined by east-west winds that move them along. These clouds, unlike those on Earth, are disrupted by storms only after hundreds of years.

Telescopes have been focused on Jupiter for nearly 400 years, and Galileo captured early views of its four large moons. Newton calculated the mass and density of Jupiter by watching the orbits of those large satellites. As of today Jupiter has 17 moons, but only the largest are reasonable observing targets and some of them are also NASA targets for ongoing research.



Jupiter's largest moons, clockwise from bottom left: Ganymede, Io, Europa, and Callisto. Ganymede has a rocky interior surfaced in thick ice. About the size of Mercury, it is heavily cratered and marked with fault lines and shearing.

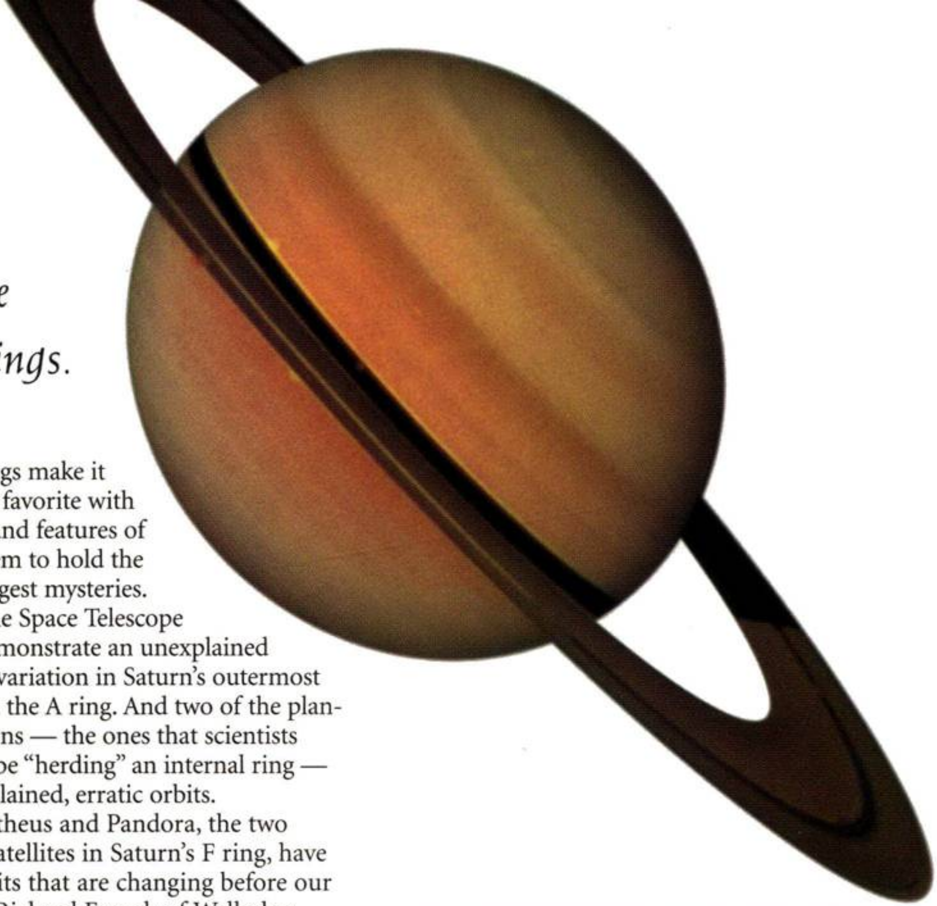
Io, recently visited by Galileo, displays hyperactive volcanism that changes the moon's surface radically and regularly.

Europa, the satellite thought most likely to hold water, has a silicate interior covered by a 62-mile crust of ice. There are few signs on Europa of mountains or craters, but its surface is etched in lines that suggest fractures.

Callisto, one of the four Galilean satellites so-named because they were first identified by Galileo, has an icy surface that is richly covered in large craters and impact scars.

Saturn

Its many moons may herd the icy debris of those fabulous rings.



Vital Statistics

Mass: 1.25 X 10^{27} lbs

Diameter: 74,898 miles

Mean density (lbs/ft^3): 43

Escape velocity:
79,400 mph

Average distance from sun:
888 million miles (9.6 AU)

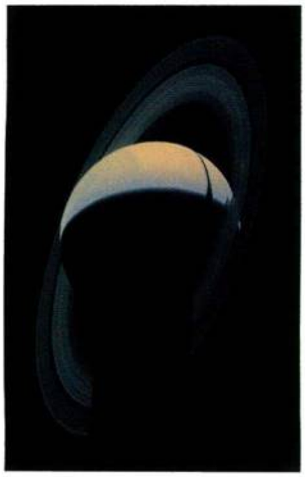
Rotation period:
11 Earth hours

Revolution period:
29 Earth years

Mean temperature: –300° F

Atmospheric components:
97% hydrogen, 3% helium,
0.2% methane

Below: Saturn's rings make it a favorite with observers. Those rings are 169,800 miles in diameter, but only tens of yards thick.



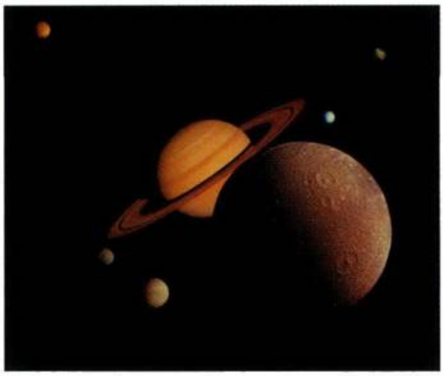
Saturn's rings make it a perennial favorite with observers, and features of its rings seem to hold the planet's biggest mysteries. New Hubble Space Telescope pictures demonstrate an unexplained brightness variation in Saturn's outermost bright ring, the A ring. And two of the planet's 18 moons — the ones that scientists think may be "herding" an internal ring — have unexplained, erratic orbits.

"Prometheus and Pandora, the two shepherd satellites in Saturn's F ring, have screwy orbits that are changing before our eyes," says Richard French of Wellesley College. "Each time we look at the satellites they're getting bumped around by something and we don't know what it is."

The A ring offers a different problem. French explains that closer to Saturn, the gravity from the planet prevents ring particles from clustering together. Farther away the tug is weaker and television-sized chunks of matter come closer to clumping together. On a quest to clump, the bodies line up like beads on a necklace producing areas of brightness.

"We're learning a lot about what it's like to be on the hairy edge of a ring trying to be a satellite but not quite able to do it," says French. While Hubble will continue to take detailed pictures of the rings, the Cassini spacecraft is en route to Saturn, due to arrive in 2004.

Cassini, the last of NASA's big budget science missions, hopes to orbit Saturn for several years, gathering hordes of information about the atmosphere, the odd storms, the rings and satellites, and more about the internal workings and origins of the gas giants. Cassini will launch the Huygens probe intended to explore Saturn's moon Titan. Titan has shown some evidence for water ice in the past, and Huygens will scrutinize the clouds, atmosphere, and surface of Saturn's moon. Saturn, a gas planet almost as large as Jupiter, also shares characteristic horizontal cloud bands. Saturn's bands hold clouds that demonstrate its own stormy weather.



- Saturn probably has even more than the 18 moons recognized in its orbit. Most of the moons were formed as the planet took shape, but some were probably captured by the planet's gravity.

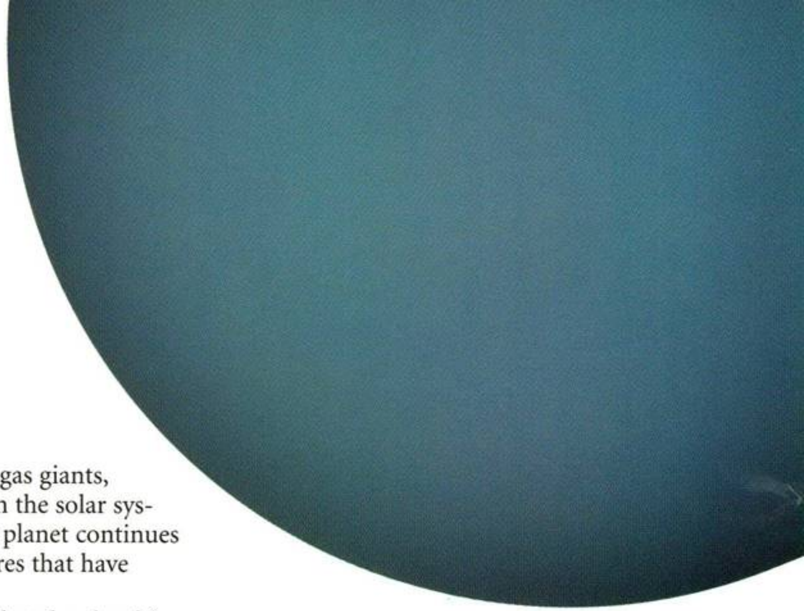
- Saturn is the sixth planet from the sun and second largest in the system.

- Its rings, made of ice and rock particles — some as big as Volkswagen vans — may have been pieces of comets or asteroids that broke up before they reached the planet.

- In the 1970s, Pioneer 11 collected data as it flew by Saturn, and in the 1980s, the Voyagers did the same. The Cassini spacecraft, launched in 1997, will arrive for a far more thorough study of Saturn and its moons and rings in 2004.

Uranus

Tilted by collision with a mighty heavy object.



Vital Statistics

Mass: 1.91 x 10^{26} lbs

Diameter: 31,763 miles

Mean density (lbs/ft^3): 81

Escape velocity:
47,600 mph

Average distance from sun:
1,784 million miles (19.2 AU)

Rotation period:
17 Earth hours

Revolution period:
84 Earth years

Mean temperature: –350° F

Atmospheric components:
83% hydrogen, 15% helium,
2% methane (at depth)

Rings: Earth-based occultations and observations from Voyager 2 suggest that Uranus is encircled by 11 narrow rings consisting of dark dust particles.

Uranus may have an extremely weak internal heat source or, unlike the other gas giants, it may have none.

Uranus, third of the four gas giants, has the brightest clouds in the solar system. As time goes on, the planet continues to reveal new cloud features that have never been seen before.

"What's interesting is that the clouds' hemispheres don't seem to be symmetrical," says Erich Karkoschka of the University of Arizona. "There is a big difference between north and south and in the brightness and color. At the moment it's not clear if that's intrinsic or a change that comes with the seasons. The clouds are either getting brighter or there are more on the front side of the planet."

Because a year on Uranus lasts 84 Earth years and the blue-green planet rotates on its side, planetary scientists have not seen the side coming into view now since the 1960s when imaging equipment was not what it is today. As Uranus's dark hemisphere appears, high northern latitudes will be seen as if for the first time. While much slower than Earth in making its way around the sun, Uranus's rotation is much faster than Earth's: 17 hours, 14 minutes.

While Jupiter and Saturn are more massive than Uranus, Neptune is close to the same size and density. The atmospheres of all four are mostly hydrogen and helium, but the atmospheres of Uranus and Neptune surround huge cores of rock and ice. Like the other gas giants, Uranus is at the center of a collection of moons and rings. As of this morning, Uranus had 17 recognized moons, with four others reported. Its dark rings are nearly impossible to see from Earth.

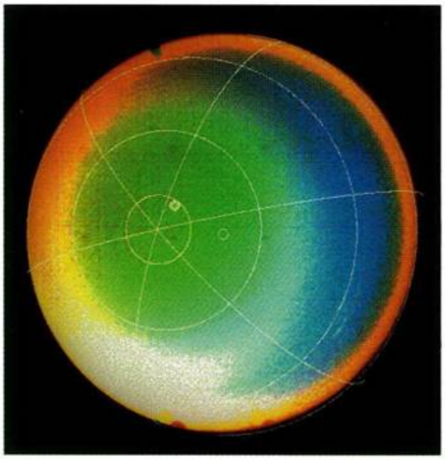
Uranus must have suffered a major collision with a very large object. It seems to be tipped on its side compared to all the other planets in the system. Its equator runs perpendicular to the orbit of Uranus around the sun. The rotational and orbital axes of this gas giant are nearly aligned, and because of this, we see Uranus pole-on every 42 years.

The moons and rings of this icy planet orbit it in its equatorial plane, so the whole system is tilted away from the plane of the planet's solar orbit.

- Uranus was discovered in 1781 by William Herschel.

- Uranus may be the strangest planet in our neighborhood because it (accompanied by its entire satellite and ring system) rotates on its side.

- This odd configuration may be the result of a harsh encounter with a tough, heavy, fast comet that knocked the planet on its side many millions or billions of years ago.



- The Voyager 2 spacecraft visited Uranus in a 1986 flyby.

- Uranus is at the center of its own rich satellite system. It holds five major moons in its orbit: Ariel, Umbriel, Titania, Oberon, and Miranda. Another 10 minor satellites were discovered by Voyager 2 to be orbiting inside of Miranda. Six distant moons have been tentatively discovered. The surfaces of the major moons suggest that volcanism and impacts have shaped them.

Neptune

Infrared camera captures details of a faraway planet.

Vital Statistics

Mass: 2.27 x 10^{26} lbs

Diameter: 30,775 miles

Mean density (lbs/ft^3): 102

Escape velocity:
52,600 mph

Average distance from sun:
2,794 million miles (30 AU)

Rotation period:
16 Earth hours

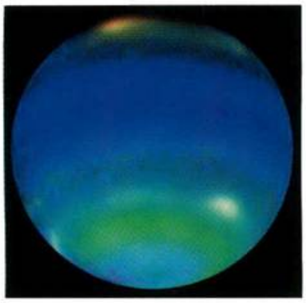
Revolution period:
165 Earth years

Mean temperature: –370° F

Atmospheric components:
79% hydrogen, 18% helium,
3% methane

Rings: Neptune is encircled by a collection of six rings that are narrow and contain concentrations of particles called ring arcs.

Neptune's system includes six small moons discovered by Voyager 2 and two substantial moons: Triton and Nereid.



Uranus's near twin Neptune, an icy planet of about the same mass, density, and composition, is so remote from Earth, on average 2.8 billion miles away, it has been a challenge to scientific understanding. Now Neptune is being seen like never before. Cornell researchers have built an infrared camera that provides detailed images of the planet that are unaffected by atmospheric turbulence. Built for the 200-inch Hale Telescope at Palomar Mountain Observatory, the Palomar High Angular Resolution Observer coupled with a new adaptive optics system developed by JPL can provide high spatial resolution simultaneously with spectral information giving fine details of Neptune.

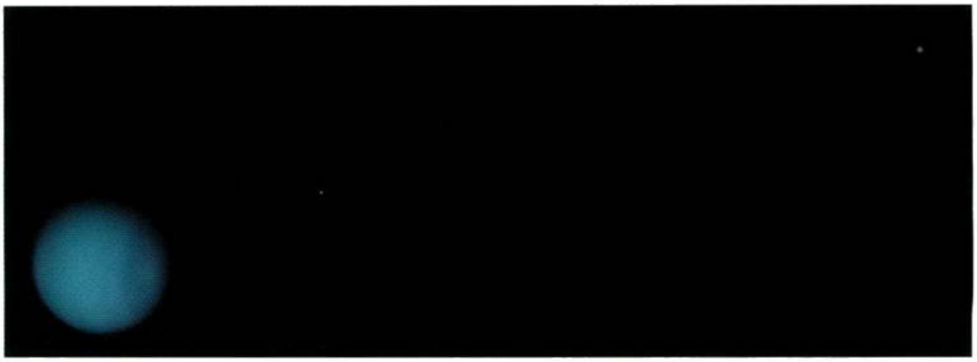
New images show a massive cloud on Neptune about the size of Europe, as well as numerous smaller clouds. With new, sharper images of Neptune, scientists will be able to determine the compositions and altitudes of the clouds.

Neptune is also at the center of a system of moons (eight identified so far) and dark rings. Its largest moon, Triton, orbits Neptune clockwise, opposite the orbits of all the planets around the sun and all the major moons around their planets. Almost everything else moves in a counterclockwise pattern, to which Triton rebels.

The explanation for this retrograde orbit is that Triton was once captured by the gravity of Neptune when it came too close. Triton is made of rock and ice and resembles the ninth planet Pluto much more than it does Neptune. Its surface is rich in water ice, dry ice, and frozen carbon monoxide, methane, and nitrogen. Cold geysers spit frigid vapor instead of the hot waters that get spewed out in Earth's hot springs.

- The discovery of Neptune by Johann Galle and Heinrich D'Arrest occurred at Berlin Observatory in 1846.
- Neptune's Great Dark Spot is a storm in the planet's atmosphere similar to Jupiter's Great Red Spot.
- Neptune is the most distant from the sun of the four gas giants.
- In 1989, Neptune was the last stop for Voyager 2 on its tour of the solar system.

Neptune is orbited by eight moons including the largest one, shown below, Triton.



Pluto

So distant from Earth, we can't see its surface.

Vital Statistics

Mass: 2.76×10^{22} lbs

Diameter: 1,485 miles

Mean density (lbs/ft^3): 109

Escape velocity:
2,500 mph

Average distance from sun:
3,647 million miles (39.5 AU)

Rotation period:
6 Earth days

Revolution period:
248 Earth years

Mean temperature: –390° F

Atmospheric components:
perhaps methane and nitrogen

Surface materials:
perhaps methane ice

Many planetary scientists believe Pluto is a minor planetary body and should be reclassified an asteroid. In 1999 a dispute erupted between those who suggested giving Pluto an asteroid number and those who fought hard to keep it designated a planet, as it had been since Clyde Tombaugh discovered it. It is, after all, round unlike most asteroids and traditionally recognized as our ninth planet. On the other hand, Pluto is smaller than seven of the moons that orbit other planets in the solar system.

- Pluto was discovered by Clyde Tombaugh at Lowell Observatory in 1930.
- Pluto is the farthest known planet from the sun and the only one that no spacecraft has visited.
- NASA is now developing a robotic reconnaissance mission that scientists hope will launch in time to reach the distant planet about 2010.

The Hubble Space Telescope has taken several close looks at the ninth planet Pluto and its giant moon, Charon. The surface of Charon is covered in water ice, according to Mark Buie of the Lowell Observatory. A detailed spectrum of Pluto, currently being analyzed, will probably show methane, nitrogen, carbon monoxide, and water ice on the planet's surface. "We are trying to untangle the distribution and understand it relative to the visible maps," says Buie.

"Pluto is what we're most interested in, but there may be some things happening on Pluto that are masked by Charon's presence," says Buie. Pluto is the only planet in the solar system with a satellite close to its own size and brightness, leading some astronomers to think of the two as a double planet. Although the sizes are not known exactly, Charon is probably 780 miles in diameter, and Pluto, the smallest planet, 1,430 miles in diameter. Pluto is so far away from Earth (and the sun) that scientists have no accurate idea about its surface features. We do know it has an elliptical orbit around the sun; sometimes it's 2.8 billion miles away from the home star and sometimes it's as much as 4.6 billion miles distant. And about every 250 years, Pluto's orbit takes it inside the orbit of Neptune, making it the eighth planet in the system 20 years at a time.

Pluto orbits in the Kuiper Belt, where it keeps company with thousands of small, icy bodies. Astronomers believe that the Kuiper Belt, made up of 230 known icy bodies and recognized in 1992, serves as a cometary nursery, and that Kuiper Belt comets periodically move into the inner solar system.

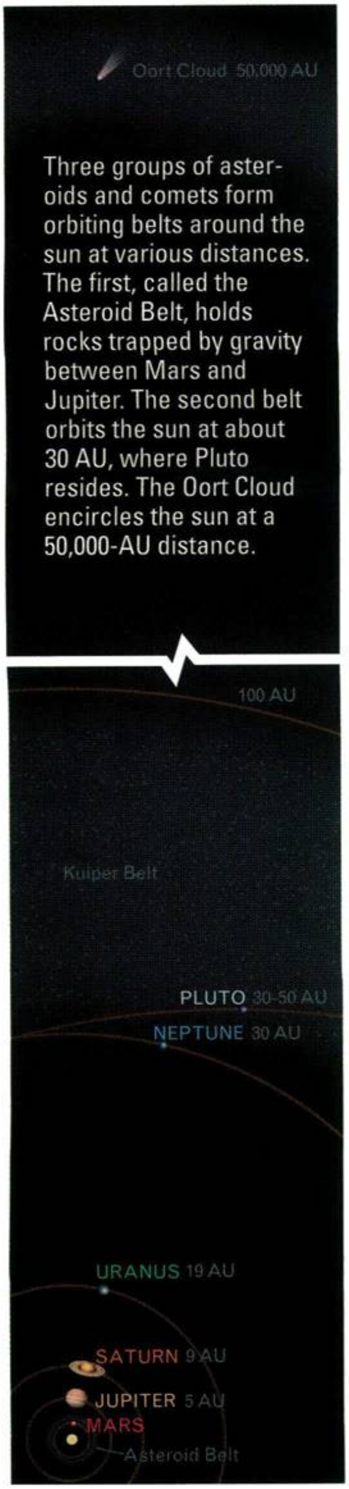
First only one of the Kuiper Belt objects displayed a highly erratic orbit, and it seemed an oddity until this year when nine more were counted, vindicating a new class of bodies called Scattered Kuiper Belt objects. Unlike the other objects in the belt with nearly circular orbits, the newfound scattered objects have extremely elliptical orbits. They dip in at 35 AU from the sun and veer out to more than 100 AU, forming a fat donut beyond Neptune. According to David Jewitt of the Institute for Astronomy in Hawaii, it's possible that all comets with elliptical orbits originate in the scattered Kuiper Belt.

"In our surveys they appear to be rare, but this is because they are only bright for a short time when they near the sun in perihelion. During the rest of the orbital period (which could be thousands of years), they are too faint to see," says Jewitt. "With the new observations we estimate there are billions of them."

Charon is Pluto's satellite and more than half as large as the planet, below.

Asteroids & Comets

A moving wreath of rocks,
the solar system's flashers.

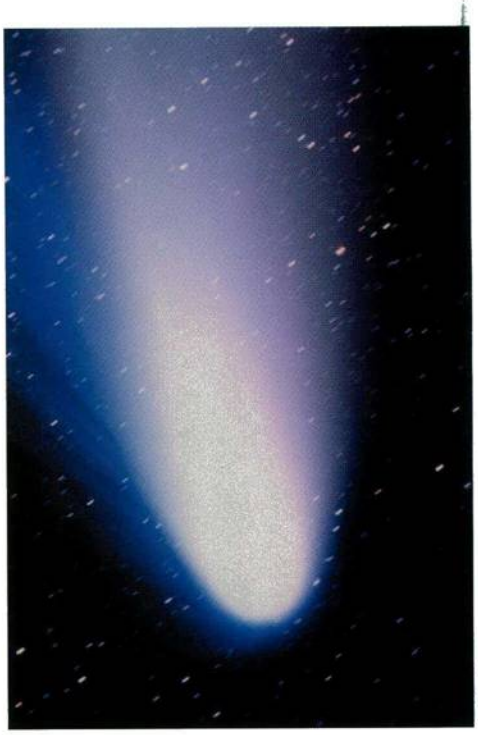


Three groups of asteroids and comets form orbiting belts around the sun at various distances. The first, called the Asteroid Belt, holds rocks trapped by gravity between Mars and Jupiter. The second belt orbits the sun at about 30 AU, where Pluto resides. The Oort Cloud encircles the sun at a 50,000-AU distance.

Asteroids are chunks of variously sized and shaped rock and metal that orbit the sun. One group of asteroids hovers between Mars and Jupiter in the so-called Asteroid Belt which is thought of as pieces of a planet that failed to shape up. These rocks never coalesced to become a planet because of the forceful gravitational pull of giant Jupiter.

Most of the 10,000-plus asteroids identified thus far are located in the Asteroid Belt, but thousands have elliptical orbits that bring them close to Earth from time to time. One possible explanation for the disappearance of dinosaurs is that an asteroid hit Earth 65 million years ago and wiped them out. Only about 170 asteroids are recognized as potentially hazardous to Earth today, meaning that their orbits bring them too close for comfort. Observers work diligently to spot and track potential comet hazards. As of the moment, none threatens. In 1991 and 1993 NASA's Galileo spacecraft studied two asteroids, and in 1996, NASA launched the Near Earth Asteroid Rendezvous so that it could meet with and study Eros and Mathilde.

Very large asteroids, often called minor planetary bodies, are large enough so that their own gravity shapes them into spheres. Ceres and Vesta are two of these. Other asteroids such as Ida have moons of their own.


Jay Ouellet

Comet Hale-Bopp's brightness reached its zenith for Earth dwellers in 1997. It came to us an unexpected visitor, turning many people into temporary observers.

Rock, organic compounds, and ice merge together to make comets sometimes several miles in diameter. These wandering bodies travel in highly elliptical orbits that take them from the cold dark reaches of the solar system to right up next to the sun. As a comet gets close to the sun, its nucleus warms and the ices evaporate. The trail of particles shed by the nucleus can create a tail visible from Earth.

Some asteroids, such as potato-shaped Ida, have companion satellites. Dactyl orbits the much larger Ida, below.

Comets may have carried water to Earth changing its climate and environment.

Throughout history, the appearance of comets has held special meaning for people on Earth. They appear suddenly and are thought to carry unhappy portents, but in truth they may have made life on Earth possible. Comets are one of the most exciting of the sky's displays, and an interest in them has brought many amateur astronomers to the hobby.

The Stardust spacecraft, launched in 1999, is attempting to collect dust from Comet Wilde 2 and return it to Earth. ▪

Raving Over

A new class of huge telescopes promises to reinvigorate ground-based astronomy.

by Steve Nadis

Telescopes, at least in one respect, are like people. Every 20 to 30 years, a new generation takes center stage. The older models may generate useful data for some time, but their work gradually attracts less of the limelight. At the dawn of the twenty-first century, an unprecedented number of large, ground-based telescopes are either operating or soon to come online. The largest of these instruments are in the 8- to 10-meter class, including the two Keck telescopes, Subaru, and Gemini North on Hawaii's Mauna Kea; Gemini South on Cerro Pachón in Chile; the Very Large Telescope, a four-telescope array on Cerro Paranal in Chile; and the Hobby-Eberly Telescope at the McDonald Observatory in the Davis Mountains of Texas.

ESO galaxy 269-57 is captured by one of the four 8.2-meter telescopes from the European Southern Observatory's Very Large Telescope. European Southern Observatory

Big Scopes

"These telescopes are not only bigger, but better," says University of Wisconsin astronomer John Gallagher. "They'll produce sharper images and enable you to get more data, faster. For some observations, they should surpass the 2.4-meter Hubble Space Telescope." This new class of instruments, he adds, represents a significant increase in the number of large telescopes, which means that a diverse range of observational programs can be supported.

Larger mirrors collect more light, bringing fainter and deeper objects into view. "A major hope for the big telescopes is that they will allow us to learn how galaxies formed," says University of Washington astronomer Bruce Margon. But the telescopes should also provide unprecedented views of nearby stars in the Milky Way Galaxy. Astronomers expect to observe planetary systems forming around other stars and detect faint stars that were previously overlooked. These faint objects, Margon notes, may prove to be the dominant contributor to dark matter in the universe.

At the present time, it's impossible to say what the most important contributions will be. "We had ideas of what we might learn when we started building 4- to 5-meter telescopes some decades ago, but so much that came from them was unexpected," says Todd Boroson of the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona. "It is for their unexpected discoveries that these telescopes are most known."

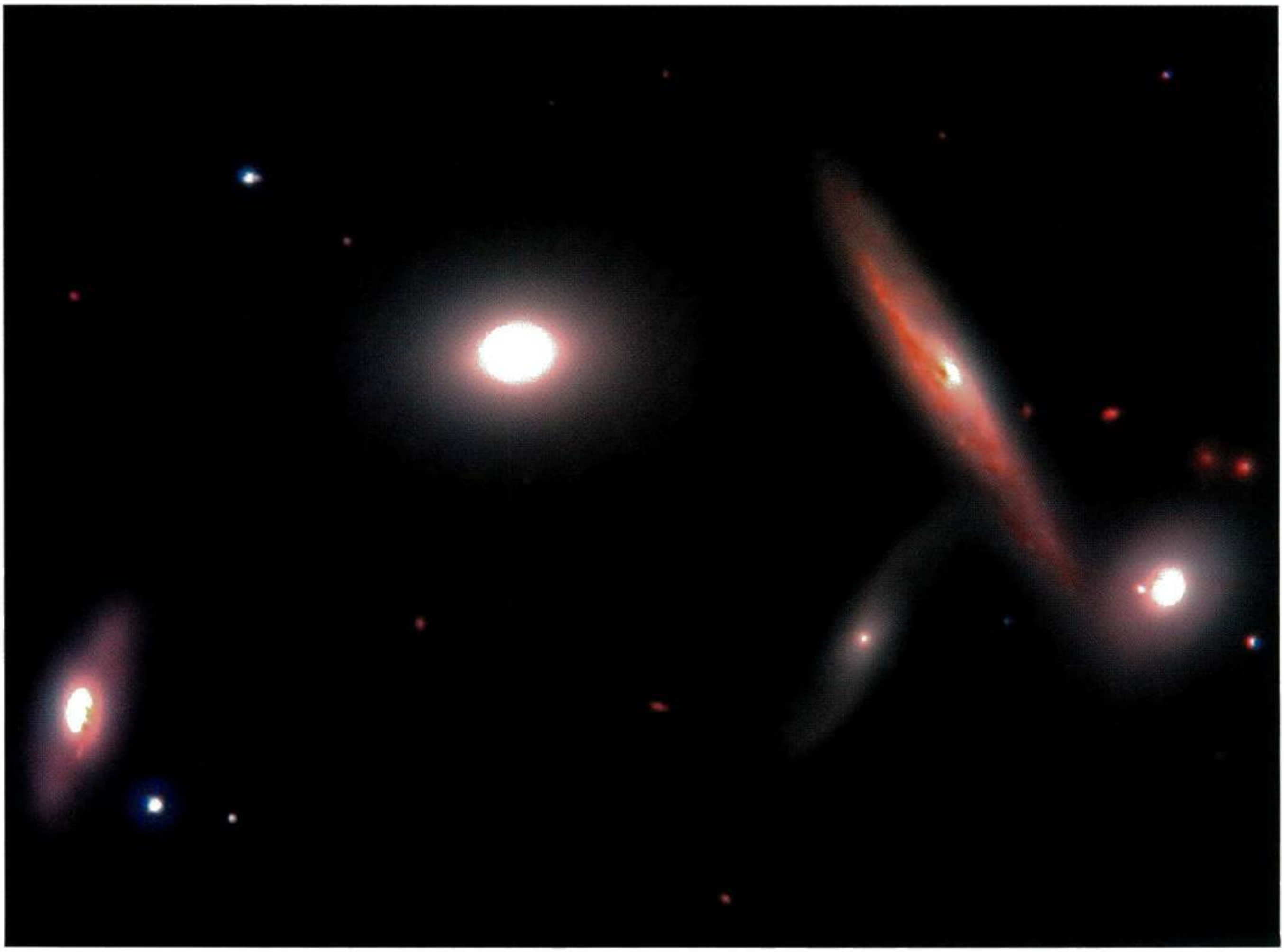
Subaru

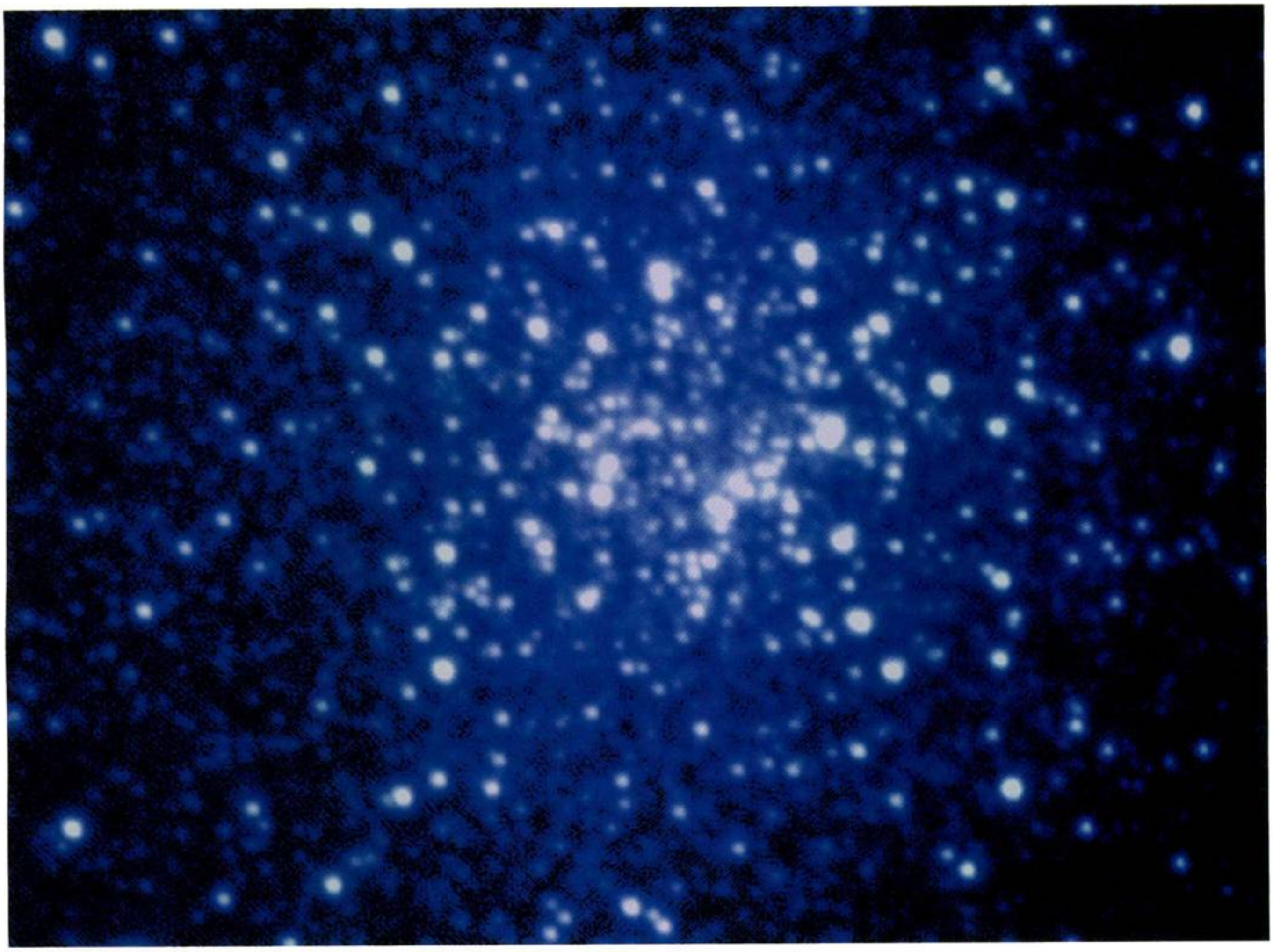
With its 8.3-meter mirror, the Subaru Telescope on Mauna Kea is the largest single-mirror telescope in the world. It represents Japan's first foray into the realm of big-time optical and infrared astronomy. The telescope is currently being fine-tuned and should become available to outside astronomers late in 2000.

"Our goal is to have the sharpest telescope in the world," says Subaru director Norio Kaifu. Even at this early testing stage, the telescope has achieved better than 0.2 arcsecond in angular resolution, or image sharpness, which is quite possibly a record for a ground-based telescope that doesn't use adaptive optics to reduce the effects of atmospheric turbulence.

The telescope has already produced some spectacular images. Observations in June 1999, for example, yielded the first ground-based images that showed Pluto and its moon Charon clearly separated. The telescope discovered the

Left: Japan's state-of-the-art Subaru Telescope sits atop Mauna Kea. Below: Subaru images galaxies in Hickson Compact Group 40. Subaru Telescope, National Astronomical Observatory of Japan

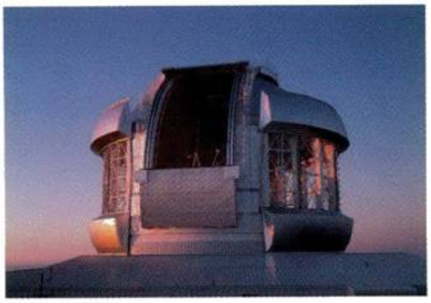




presence of ethane ice on the surface of Pluto, while confirming the existence of water ice on Charon's surface.

Several technical features contribute to Subaru's visual acuity. An array of 261 actuators (tiny motors) automatically corrects deformations in the giant mirror. "Because we have more actuators than other telescopes, we expect to be able to control the surface better," Kaifu explains. The telescope is surrounded by a unique cylindrical enclosure to minimize atmospheric turbulence that can degrade images. The adaptive optics system, due to be installed in the second half of 2000, should improve the resolution to 0.06 arcsecond — sharp enough to pick out an object the size of a baseball from a distance of about 180 miles.

Subaru is expected to make major contributions to "deep-field" research, conducting surveys of the darkest regions of space, where it can look far into the depths of space and time. These efforts will be enhanced by the telescope's prime-focus camera, which can capture images of wide sections of the sky. "It is the only one of the big new telescopes that has a large enough field of view to look at the distribution of galaxies in space," notes Gallagher. Ultimately, this work should provide insight on how galaxies form.

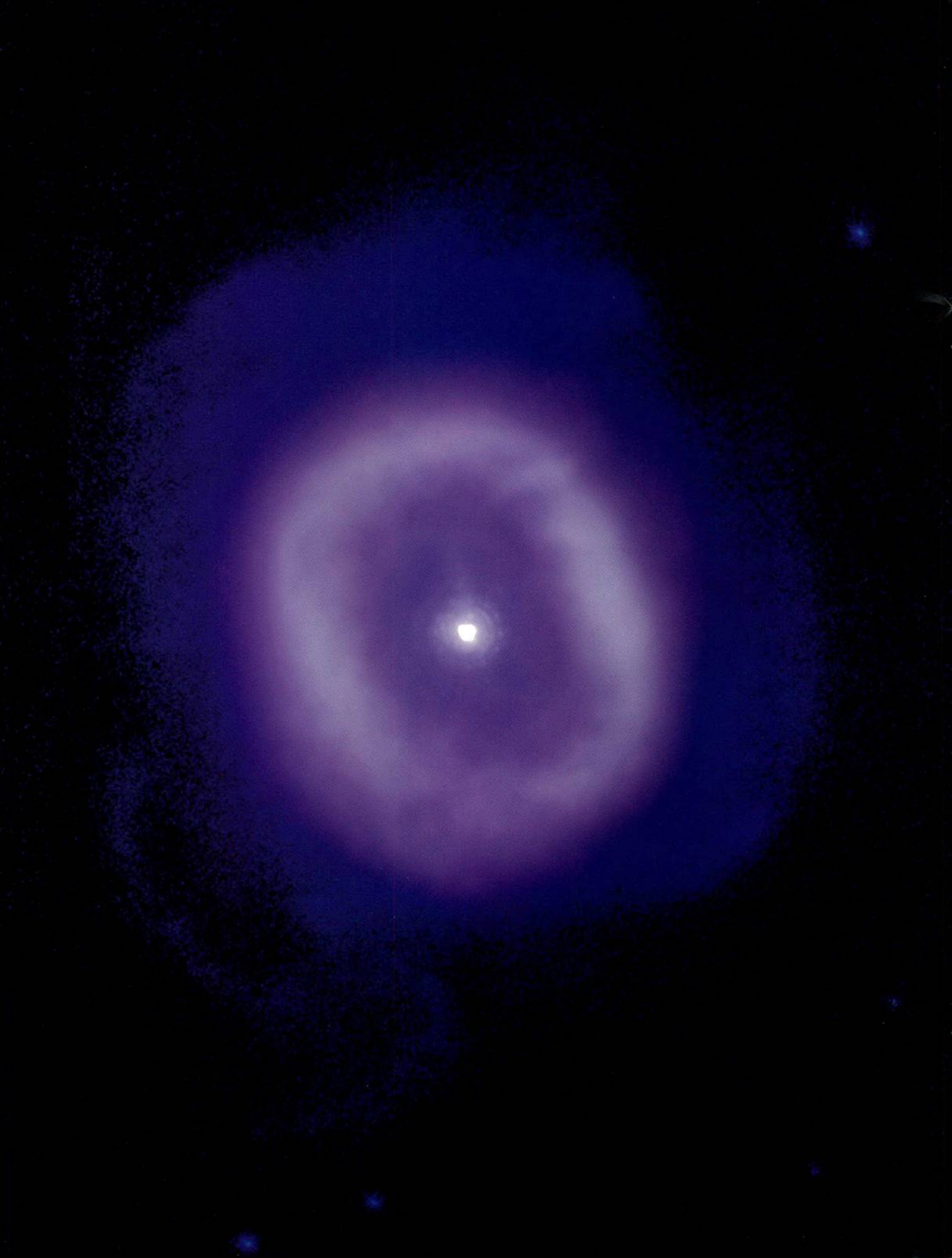


Above: Gemini North resolves thousands of stars in the core of globular cluster NGC 6934. Left: Gemini North is just a stone's throw from the Keck and Subaru telescopes on Mauna Kea. Gemini Observatory/NSF/University of Hawaii Institute for Astronomy

Kaifu believes Subaru may be the first telescope to image planets directly. Its coronagraphic imager screens out starlight so that astronomers can search the vicinity of a star for orbiting bodies. The instrument, used in conjunction with adaptive optics, is designed for infrared operation, which makes sense because planet-forming regions are shrouded in dust. Though heat can escape, very little visible light makes it through the haze. Coronagraphs are a standard item on telescopes, Kaifu admits, "but our instrument is optimized for an 8-meter telescope, optimized for infrared, and optimized for adaptive optics. We hope that combination will give us the best chance of seeing planets, starting with gas giants in young systems that will be hottest and therefore brightest."

Gemini

The Gemini Observatory — consisting of two almost identical 8.1-meter telescopes, one on Mauna Kea and one on Cerro Pachón in Chile — literally spans the hemispheres. Normal operations should be underway at the northern telescope in early 2001 and at the southern facility later that year. The United States has funded about half of



the $184-million project, with the remaining costs shared by Australia, Argentina, Brazil, Canada, Chile, and the United Kingdom.

To get the maximum benefit from Gemini, the strategy has been to optimize each telescope for different uses, explains director Matt Mountain. "We want the northern telescope to be superb for infrared astronomy and the southern telescope superb for ultraviolet astronomy."

In the first images taken by Gemini North, the telescope demonstrated a capability to resolve astronomical objects just 0.08 arcsecond apart, equivalent to resolving a car's two headlights at a distance of 2,000 miles. The crisp vision is owed, in part, to efforts to lower the telescope's own background glow. Thermal emissions from the telescope are only about one-third those of most other telescopes. Other image-enhancing features include a moveable secondary mirror that minimizes star twinkling, plus an adaptive optics system that helps compensate for atmospheric turbulence. With 11 times the collecting area of Hubble, each Gemini telescope can see deeper, with comparable resolution, for a fraction of the cost.

The overriding theme for both telescopes, says Mountain, is a "search for origins." The telescopes will look deep in space, and far back in time, for clues about the formation and evolution of galaxies, while also studying the structure of our own galaxy.

"Gemini astronomers," adds Boroson, "will make major contributions to understanding how stars form," as observations of stellar nurseries are best made in the infrared to see through all the dust. Gemini will also probe the dusty disks found around young stars, which may be precursors to planetary systems.

Astronomers have put forth proposals to link Gemini via fiber-optic cables with its Mauna Kea neighbors, Keck I and II and Subaru, to create a giant infrared interferometer that would boost Gemini's resolution fiftyfold. If these plans go forward, this powerful tool might be available within a decade for a variety of applications. "We could study the surface of other stars, for example, just as we study the sun today," says Mountain.

Meanwhile, the Gemini team is preparing to install an advanced adaptive optics system on its southern telescope in 2004. The system will rely on five lasers to create artificial "guide stars" in the atmosphere that help permit corrections for distortion. "If it works as well as planned, we'll install it in the north too," says Mountain. With these improvements in resolving power, Gemini might then compete with Hubble's successor, the Next Generation Space Telescope, whose launch is planned for later this decade.

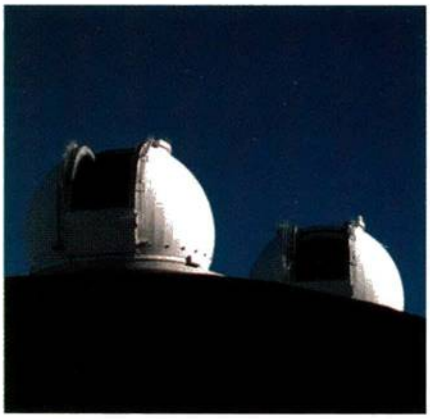
The Kecks

The twin 10-meter Keck telescopes, the first of the current generation of giant mirrors made of hexagonal segments, are the world's largest optical and infrared telescopes. From the nearly 14,000-foot summit of Mauna Kea, Keck I and II began scientific observations in 1993 and 1996, respectively. Together, these instruments have "dominated" ground-based optical and infrared astronomy for the past half decade, says Boroson.

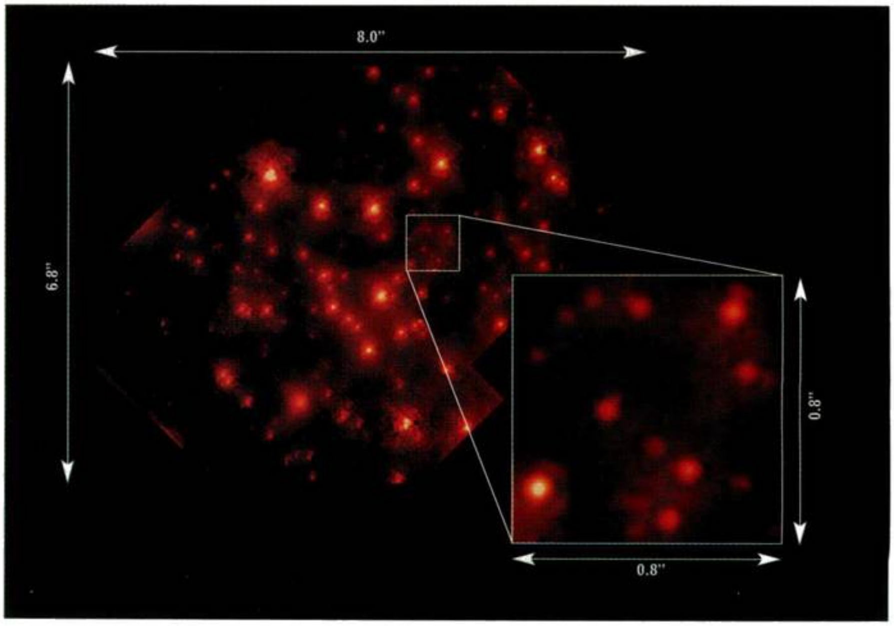
About 90 percent of the observations at Keck involve taking spectra — that is, separating the radiation from celestial objects into distinct bands, or colors — rather than obtaining images. Spectroscopic observations are more light intensive than imaging, which is what gives the large new telescopes an edge over Hubble. Researchers have used the Keck telescopes to examine faint objects discovered by Hubble in far greater detail. These spectral measurements have enabled astronomers to calculate the distance to objects in the Hubble Deep Field survey by determining the extent to which their light has been shifted to longer (redder) wavelengths by the expansion of the universe. This knowledge, in turn, has facilitated the construction of three-dimensional maps of the universe. The biggest surprise, says observatory director Frederic Chaffee, has been seeing that a complex structure of galaxies and voids was already in place more than 10 billion years ago.

Observations of distant supernovae at Keck have led theorists to postulate

Left: This Gemini North infrared image of planetary nebula BD+303639, taken with adaptive optics, is sharper than a Hubble image of the same object taken in visible light. Gemini Observatory/NSF/University of Hawaii Institute for Astronomy



Left: The twin Keck 10-meter telescopes are currently the world's largest optical and infrared scopes. Below: Using adaptive optics, Keck II resolves individual stars in the center of the Milky Way Galaxy. W.M. Keck Observatory



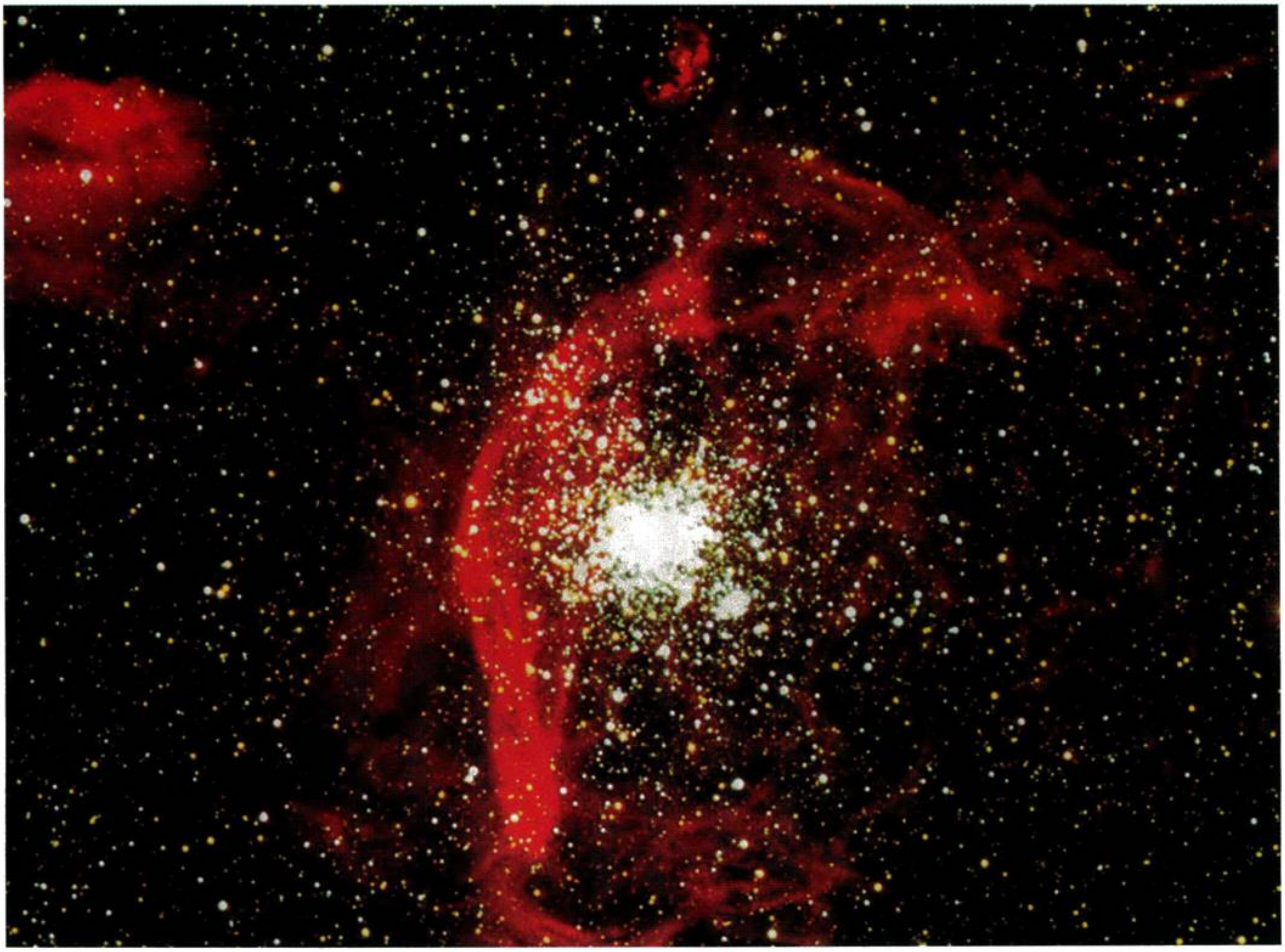
the existence of a repulsive force that is giving the expanding universe an added kick. Recent spectral analyses have shown that gamma-ray bursts emanate from far outside our galaxy. In addition, 14 of the approximately 45 extrasolar planets discovered to date have been discovered at Keck, and that number is sure to rise.

High performance at Keck, as well as at other new telescopes, has been achieved through a computer-controlled "active optics" system that keeps the primary mirror aligned and counteracts the effects of gravity and temperature. This is done by means of actuators that adjust each of the primary mirror's 36 hexagonal segments, twice per second.

Further improvements have been made since 1998 with the installation of a $7.5-million adaptive optics system. The system employs deformable secondary mirrors that move roughly 1,000 times a second to cancel out the blurring effects of the atmosphere. Under optimal conditions, the system can improve resolution at Keck tenfold. It has already been used to reveal volcanic eruptions on Jupiter's moon Io, and to obtain some of the best pictures of Neptune since the Voyager 2 spacecraft took close-up images in 1989. "Before, Neptune was just a smudge to ground-based observatories," says Chaffee. "Now we can see its weather systems." The adaptive optics system has also allowed images of galaxies to be taken with the light from other galaxies separated rather than added together.

Sometime next year, plans call for linking the two large Keck telescopes and four smaller ones to form an interferometer. Using the telescopes in this mode should yield another tenfold increase in resolution. Once this is done, astronomers will be able to take pictures of Jupiter-sized planets orbiting other stars. "But with the new capabilities in place, the hard work really begins — trying to figure out the best ways to realize the scientific benefits of these instruments," says Chaffee.

Right: Europe's Very Large Telescope is actually four telescopes in one. Starting in 2002, they will be used in concert to form a giant interferometer. Below: NGC 1850 is imaged by one of the four VLT telescopes. European Southern Observatory



The Very Large Telescope

On the flattened summit of Cerro Paranal, 8,635 feet above the Atacama Desert in northern Chile, stands what some have called the most modern observatory in the world. Operated by the European Southern Observatory

(ESO), an eight-nation consortium, the Very Large Telescope (VLT) is actually four 8.2-meter telescopes. Three of the four telescopes have already seen first light, and the fourth telescope should be running by 2001. At that point, VLT will become the largest optical telescope in the world. It will span the electromagnetic spectrum from near-ultraviolet to mid-infrared wavelengths with a combined light-gathering ability equivalent to a 16.4-meter telescope.

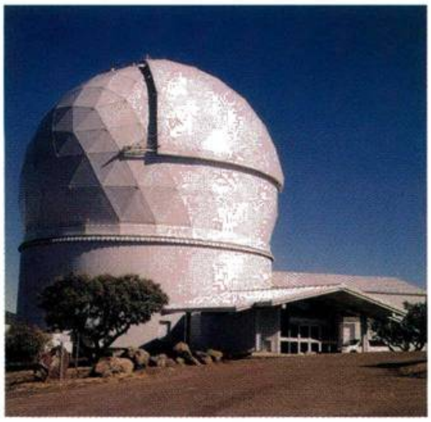
The first interferometry measurements are scheduled for 2002. Light from the four large VLT telescopes, plus three 1.8-meter telescopes, will be melded together, forming a giant instrument with the image clarity of a 130-meter telescope. This device, if it works as expected, could resolve the separate beams of a car's headlights 400,000 miles away — a distance about equal to a round trip between Earth and the moon.

Beyond its sheer size, the VLT also offers benefits in terms of efficiency and ease of use. The telescopes can be pointed very quickly, says Johns Hopkins University astronomer Riccardo Giacconi, former director-general of ESO and former director of the Space Telescope Science Institute. "It takes just 1.5 minutes to go from one source to another, which is not the case with other telescopes. That makes you more effective because you can do more observing in the course of the night." Another attribute, says Gallagher, is that the telescopes are specifically designed to complement one another. "VLT will stand out because of its versatility. You have four telescopes, each with at least three instruments, which means you can quickly bring a dozen capabilities to bear on a problem."

Early observations from the first VLT unit telescope to come online have determined a 7 billion light-year distance to a gamma-ray burst that was observed on May 10, 1999. VLT studies within our galaxy have demonstrated that stars of all masses — including small and faint ones, not just the heavy and bright ones previously seen — are born together in so-called "starburst" regions. Other recent observations have laid the groundwork for measuring the age of white dwarf stars, which are thought to be among the oldest objects in the universe.

Future plans call for peering into the center of our galaxy and our nearest galactic neighbors, the Small and Large Magellanic Clouds — work that can only be done from the Southern Hemisphere. VLT will also be turned loose to probe the regions around supermassive black holes in our galaxy and others. As with the other new telescopes, astronomers intend to use VLT to search for planets around other stars and to shed light on the mystery of galaxy formation.

The possibilities are vast, and new findings will undoubtedly suggest additional ways of exploiting this powerful instrument. "VLT shows that a tremendous amount of science can still be done from the ground," Giacconi notes.



The Hobby-Eberly Telescope has a larger mirror than the Kecks, but only a part of its mirror can be used at a given moment. McDonald Observatory

Hobby-Eberly

Situated in remote southwest Texas, the Hobby-Eberly Telescope (HET) is a monument of innovation. Its primary mirror is a hexagon 11 by 10 meters in diameter — the largest in the world — but has a fixed declination, so only 9.2 meters of the mirror can be used at any one time. Despite its large size, the telescope was constructed for just $13.5 million, a small fraction of the typical sum for large telescopes, owing to a novel concept by Lawrence Ramsey and Daniel Weedman of Penn State University. "It broke the cost curve for building large telescopes by a factor of five," notes Boroson. As a cost-saving measure, the mirror is fixed in elevation (though it can rotate in azimuth), which gives the telescope a limited ability to follow an object across the sky. But the fixed elevation makes it well suited for large-scale surveys that would be too expensive to undertake at comparably sized telescopes.

HET is already backing up the Chandra X-Ray Observatory, obtaining optical spectra of numerous x-ray sources. It is also doing spectroscopic follow-up for the Sloan Digital Sky Survey, looking at faint objects that the 2-meter Sloan telescope cannot resolve. In addition to surveys, HET's other primary mission is to study phenomena that vary over time, such as supernovae, active galactic nuclei, gamma-ray bursts, and variable stars. "The spectra of supernovae are always changing, but they are poorly understood because no one has been able to collect enough data," says Ramsey. "We can look at an object for months to get a better handle on the physics."

The study of variable objects will be facilitated by HET's unusual "queue scheduling" system. In general, astronomers don't come to the telescope. Instead, a resident astronomer chooses the best object to examine at a given time from a list of approved projects. "Your object might be observed once a week or every night for a few minutes," Ramsey says. "That's hard to do at conventional telescopes where you normally have just a few nights per year." The hope is that HET will support science that can't be done at other telescopes because of high demand. "This is really an experiment," Ramsey stresses. "We're trying to see if this is an effective way to do astronomy, and I don't think the answer is in yet."

Maybe not, but the Hobby-Eberly partners are helping an international consortium led by South Africa build a 9-meter telescope based almost entirely on the HET design. And a NOAO-led consortium has already proposed a 35-meter "Extremely Large Telescope" based on HET. If and when this instrument is built, along with others planned in the 30- to 100-meter range, a new era of astronomy will begin, following up on the discoveries of the current crop of large telescopes.

Collectively, Keck I and II, Subaru, Gemini North and South, the Very Large Telescope, and the Hobby-Eberly Telescope promise to reinvigorate ground-based astronomy. While using these new instruments to probe the cosmos in unprecedented detail, astronomers are destined to see things never contemplated before. ■

Steve Nadis is a freelance science writer based in Cambridge, Massachusetts.

Capture the Sky on Film

Photographing the night sky is easier than you think.

by David Healy

Improvements in films and amateur telescopes have made taking good astronomical photographs easier than ever before. Though plenty of digital (CCD) cameras are on the market, a wide variety of celestial portraits can be shot with conventional photo equipment, especially in color, that CCDs still can't match. The moon, constellations, occultations, and star trails are just a few of the objects easily captured with a standard camera mounted either on a simple tripod or on a telescope equipped to follow the sky. Finely detailed color portraits of deep-sky objects are possible with guided through-the-telescope photography.

To shorten the steep learning curve, we'll outline how to choose a camera and film and take you through three basic methods of astrophotography: camera-plus-tripod photography, piggyback photography, and through-the-telescope photography. We'll also touch on several choice photographic targets, polar alignment, wide-angle and telephoto lenses, focusing, guiding, and developing your photographs.

You can take beautiful pictures of star trails by simply mounting your camera on a tripod, pointing it toward Polaris, and taking a long-exposure photograph. Joshua Vaughan

Cameras: Go Primitive

Start with a 35mm camera body — the more primitive the better. The new digital and autofocus models were not designed with 40-minute cold weather exposures in mind. In such situations, they usually exhaust their batteries and promptly shut down. Ideally, the astrophotographer should use a 35mm camera with interchangeable lenses and a strictly mechanical body whose shutter can be held open indefinitely with a locking cable release. The camera will be attached to a telescope by means of a T-adapter. New, manually operated 35mm cameras are increasingly rare, but a thriving market in used 35mm camera bodies exists: Consult your local camera store or ads in the back pages of such publications as *Popular Photography*. Models such as the Olympus OM-1 and the Pentax K1000 are suitable for astroimaging.

The standard ground-glass focusing screens in the viewfinders of many 35mm cameras are perfectly adequate for snapshot photography. Unfortunately, they produce images that are too dim to allow focusing on stars or seeing faint deep-sky objects such as nebulae and galaxies. Focusing on astronomical targets is easy using wide-angle or telephoto lenses — just turn the focusing wheel to infinity. With through-the-telescope photography, focusing is trickier and even more critical. Several camera models, including the Olympus OM, Nikon F, and Pentax LX series, have interchangeable focusing screens. Orion Telescopes and Binoculars offers bright focusing screens for many of these models.

Green Sky at Night, Imager's Fright

At the risk of oversimplification, it's okay to use your favorite print or slide film (Kodak Gold, Fuji Superia, Sensia) if you are taking short exposures of bright objects. Examples include a 5-second exposure of the crescent moon and Venus setting over the mountains at twilight or a 1-second photo of a lunar eclipse.

For long exposures of dim objects, especially at the higher f/ratios typically used with long telephoto lenses or through-the-telescope photography, most snapshot films lose sensitivity and color balance, which often results in images with hazy, green skies. Kodak Ektachrome P1600 Professional Film is an extremely fast slide film that maintains its color balance in long exposures. But there are two drawbacks to Ektachrome P1600. First, it doesn't record as much fine detail as other films, which makes the image grainier. Second, it requires special processing. To achieve its rated ISO speed of 1600, instruct your favorite photo lab to use "Push 2" processing.

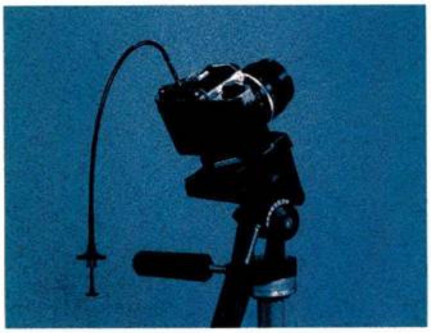
Perhaps the best all-around films for astrophotography are Kodak's PPF 400 Professional Film and Professional Ektapress PJ 400 Film. Unfortunately, Kodak has discontinued both, but retailers such as Lumicon may still have supplies on hand. Order as much of this film as you can before it disappears. Kodak suggests replacing PJ 400 with Professional Supra 400 Film.

With a clock drive to track Earth's rotation, long-exposure photos reveal glorious star colors, such as those that appear in this photo of the Big Dipper.

Bill and Sally Fletcher

In my experience, Kodak Technical Pan 2415 is the best black-and-white film for astrophotography. Its very fine grain and high red sensitivity are ideal for recording faint nebulae and for use with red filters to screen out skyglow and light pollution. Although TP 2415 has a nominal ISO speed of 160, it suffers from severe loss of sensitivity at low light levels and must be hypersensitized for use in astronomy.

Hypersensitizing film (a process that involves baking the film in hydrogen for several days in a special chamber) may seem a bit much to tackle in your first week of imaging. Fortunately, Lumicon offers individual rolls of hypersensitized film including TP 2415 and others. Hypered film offers increased sensitivity, reduced reciprocity failure, and good color balance. The primary disadvantages include the fact that hypersensitization expires unless the film is freezer-stored. The film also needs to be exposed and processed promptly.



Some more-exotic film types recommended for astrophotography aren't carried by many camera stores — try Lumicon, mail-order houses such as Adorama, or ads in magazines such as *Popular Photography*.

Tripod Shots

On any clear, moonless night, load your camera with a fast color film, place it on a sturdy tripod, set the lens aperture wide open, point the camera at Polaris, and, using a cable release and the "B" shutter setting, take exposures of 5, 10, 20, and 40 minutes. Use a lens hood and a hair dryer to keep dew from forming on the lens. Voilà, you have taken your first star-trail photographs. If you're shooting the sky from Manhattan or the downtown of any other large metropolis, you will find light pollution has washed out most of your exposures. If the photo was taken from a dark site, you'll see variations in the color of stars imaged. By taking a variety of exposures, the "sky fog limit" of your site will become apparent. Take another set of exposures high in the sky along the celestial equator some 90° away from Polaris. You will notice that star trails in this region of the sky are straight lines rather than concentric circles. They're also much longer than star trails around the pole. If your luck holds, you may even catch a meteor trail. If your luck is average, you'll catch satellite trails.

This variation in star-trail length illustrates the limitations of astrophotography with a tripod. The apparent east-to-west motion of the sky causes astronomical images to trail. The amount of apparent trailing depends on whether your photo is taken near the pole or near the equator and on the focal length of the lens used.

Long-exposure astrophotos bring out faint nebulosity that can't be seen with the unaided eye. Jerry Lodriguss

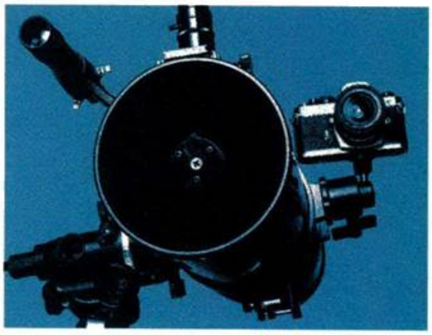
EXPOSURE

There are no hard and fast rules on proper exposure times. As I implied in my recommendation for the star-trail photographs, bracket your exposures, at least until you get a feel for your optical setup and your observing site's light-pollution limit. Try exposures of 5, 10, 20, and 40 minutes. The table below offers a few suggestions for likely targets with recommended films. The times given are a minimum starting point. Also try longer exposures of regular increments beyond the times given.

SUGGESTED EXPOSURE TIMES FOR SPECIFIC VIEWS*

FILM	SAGITTARIUS	MILKY WAY	ORION	ANDROMEDA
Kodak PPF 400 or PJ 400		30 min.	30 min.	40 min.
Ektachrome 1600P	20 min.		20 min.	30 min.
Technical Pan 2415 (hypered)		15 min.	20 min.	30 min.

*Trial exposure times (in minutes) for an f/5.6 optical system



Piggybacking It

Longer exposures that are free of trailing and bring out fainter starclouds, nebulae, and galaxies require the camera and lens be mounted on a driven platform that "follows the sky" in its diurnal motion. In practice, this usually means "piggybacking" the camera on an equatorially mounted, motor-driven telescope. There are two essentials to this type of imaging. First, the camera must be attached to the scope using the camera's tripod socket. Second, the telescope itself must be polar-aligned so that it will track the sky accurately.

Telescope makers usually offer accessory piggyback camera adapters for their scopes. In addition, Orion offers several, some of which tilt and swivel so that the camera doesn't have to point toward the same location as the telescope.

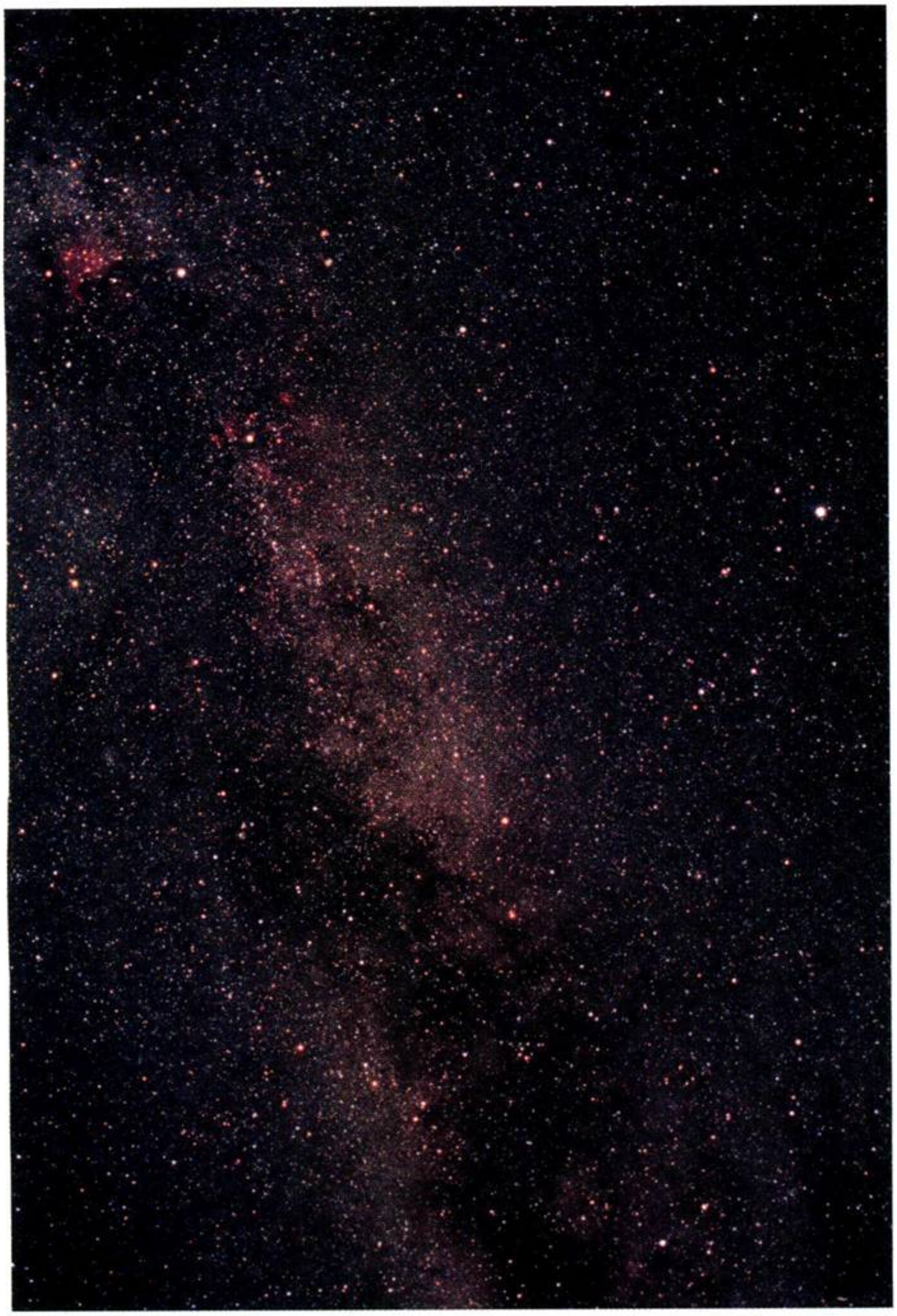
Polar alignment fine enough for good piggyback photography can be achieved by aiming the telescope's equatorial axis (or right ascension axis, the one that moves the telescope east/west) at the North Celestial Pole. First adjust the finderscope so that you can see the same object or bright star centered in both the finder and in your telescope's eyepiece. Then move the telescope in declination (along its north/south axis) to the north until the declination setting circle reads 90°. Lift and turn the telescope and its mount until the assembly is pointed roughly at the North Star, Polaris. Turn or move the scope's mount up or down (don't move the scope: it should remain pointed at 90° north) until you see Polaris in the finder.

The aim here is to point the telescope's equatorial axis and finderscope at the North Celestial Pole and not at Polaris, which is roughly 0.7° away from the celestial pole. Polaris and the pole both lie on an imaginary line in the sky that runs from the star at the end of the Big Dipper's handle (Alkaid, or Eta [η] Ursae Majoris) to the northeastern most star in the "W" of Cassiopeia (Epsilon [ε] Cassiopeiae). The pole lies 0.7° away from Polaris along the imaginary line in the direction of the Big Dipper. Many finderscopes have a field of view of about 4°, so the pole is about one-sixth of a finderscope field away from Polaris. Turn the finderscope in its mount until one of the crosshairs parallels this imaginary line. Then adjust your mounting (not the telescope) until Polaris is on the crosshair one-sixth of a field diameter away from the center of the finder. Don't forget that the typical finderscope inverts the view, so if Alkaid

This long-exposure piggyback photo of Orion brings out vivid star colors and hot bubbles of gas. Jerry Lodriguss

TARGETS & LENSES

The angular size of objects varies greatly. The Milky Way, for example, could appear 9,000 times larger than the Ring Nebula, so you use different optical setups to photograph them. The table on the right shows the fields of view for several commonly used 35mm camera lens or telescope setups. It also contains the angular sizes and angular distances of favorite regions.



is overhead, Polaris should be above the center of the field in your finder.

To Guide or Not To Guide?

Whether or not you need to guide the telescope depends on whether or not you have polar-aligned accurately and if you are using a short-focus wide-angle lens. If so, hour-long piggyback exposures with pinpoint star images may still be possible. Misaligned telescopes, high magnification, atmospheric turbulence and refraction, irregular drive motors, and wind all require adjusting or correcting the telescope's position during an exposure. It's best to routinely set up your equipment to guide every piggyback exposure, even if corrections are rarely needed.

Many amateur telescopes have a built-in, electrical east/west and north/south slow-motion control to make small pointing adjustments. Corrections are made by inserting an illuminated reticle eyepiece into the telescope, selecting a guide star before the exposure begins, and using the slow-motion controls to keep the guide star on the illuminated crosshairs of

The same technique used for Orion can yield star clouds and dark nebulae in the summer Milky Way. Jerry Lodriguss

GOING WIDE OR NARROW?

LENS OR SCOPE	COVERAGE	TARGET FIELD
17mm Wide-angle Lens	90° by 68°	Winter Milky Way (Capella to Sirius) 65°
28mm Wide-angle Lens	62° by 45°	Summer Triangle (Deneb to Altair) 38°
50mm "Normal" Lens	38° by 26°	Big Dipper (Alkaid to Dubhe) 26°
90mm Telephoto Lens	21° by 15°	Orion (Betelgeuse to Rigel) 19°
135mm Telephoto Lens	14° by 10°	Orion's Belt and Sword (Saiph to Mintaka) 8°
200mm Telephoto Lens	9.8° by 6.6°	The Hyades 8°
300mm Telephoto Lens	6.5° by 4.4°	Andromeda Galaxy (M31) 3°
8-inch SCT at f/10	0.9° by 0.6°	Lagoon Nebula (M8) 0.7°

the eyepiece during the exposure. Orion, Lumicon, Celestron, Meade, and others offer such guiding eyepieces.

Though manual guiding can be fun for the first few minutes, it quickly gets old. Santa Barbara Instrument Group (SBIG) has a small CCD camera, the ST-4, that can be inserted in the eyepiece holder and used as an autoguider. I have used the ST-4 to take two-hour guided exposures, which far exceed the posterior endurance of this human telescope operator.

Through the Eye of the Telescope

Once you've enjoyed some success with guided piggyback photos, it's time to move to more challenging, but potentially more rewarding, prime focus or through-the-telescope astrophotography. Begin by shooting bright, easy-to-find deep-sky objects. In the summer sky, try M13, the great globular star cluster in Hercules. In the winter sky, start with M42, the famous Orion Nebula.

Shooting through a telescope with hypered film can reveal exquisite detail in objects such as M8 and M20. Mike Fiest

MANUFACTURERS

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Meade
www.meade.com
949-451-1450

Orion Telescopes and Binoculars
www.telescopes.com
800-447-1001

Santa Barbara Instrument Group
www.sbig.com
805-969-1851

It's necessary to guide your prime-focus photographs with either a separate guide telescope attached to your photographic scope, or more typically, with a device called an off-axis guider. Telescope makers such as Celestron and Meade offer accessory guiders that can be fitted with "telecompressors" or focal-reducing lenses that convert your f/10 telescope to f/5 or f/6. This results in greater image brightness and shorter exposure times with some sacrifice of image scale. The off-axis guider attaches the camera body to your telescope like a T-adapter. It has a tube into which your guiding eyepiece will fit. This tube also has a small right-angle prism that plucks the image of a star from the edge of the camera's field of view and sends it up into the guiding eyepiece. Finding a good guide star can be challenging. Often, it is necessary to rotate the guider and camera to move the target around in the camera's field of view. This allows you to find a guide star that won't require contorting your body to peer through the guiding eyepiece.

Focusing a through-the-telescope photograph is also challenging. Even if your camera is equipped with a bright, ground-glass focusing screen, focusing on fuzzy objects such as nebulae is nearly impossible. If your camera can be fitted with a right-angle accessory finder, by all means get one. I strongly recommend that you set up for guided exposures by moving your telescope to a bright star and painstakingly focusing on that star. Take several trips through and beyond the best focus. Then move your telescope back to the target.

AVOID STAR TRAILS

Here's a rough guide to the longest fixed-camera exposures you can take with lenses of various focal lengths, without noticeable star trailing on your enlargements. The times are given for the worst case scenario, at the equator.

17mm	40 sec.
28mm	25 sec.
50mm	14 sec.
90mm	8 sec.
135mm	5 sec.
200mm	4 sec.
300mm	2 sec.

You don't need a big telescope to take lovely astrophotos. This moon shot was taken through a 3½-inch scope. Donald Lammon

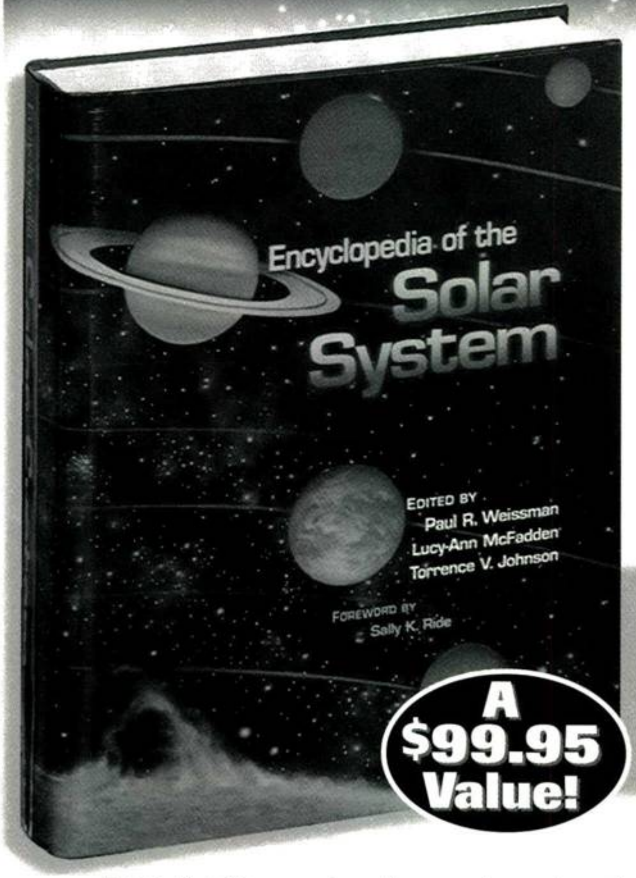
Processing: The Final Frontier

Most photo labs do an acceptable job developing astronomical slides and negatives. But it's safer to start each roll of film with a conventional snapshot. This standard exposure helps the lab distinguish dark sky from the unexposed border between frames, which reduces the chance of your precious negatives or slides being cut in half. Though they do a reasonable job developing the negatives, most photo labs come up short in making prints and enlargements. Your best defense is to educate the personnel at your favorite photo lab. Ask them to print for a "neutral dark-gray sky background;" this should reduce the chance of receiving prints with green skies and purple stars.

Film astrophotography is an enjoyable way to capture your favorite astronomical sights. Not only can we image a wide variety of objects, but new technology enables us to scan the slides or negatives, process them to our liking, and produce photo-quality enlargements on a high-resolution color printer. If film astrophotography has a promising future, and I believe it does, it is due, in large part, to the digital revolution that is making conventional print-making obsolete. ■

Veteran astrophotographer David Healy practices his craft from his home in Arizona. He authored four articles about astrophotography for the June 2000 issue of Astronomy.

Journey to the far reaches of the Universe...



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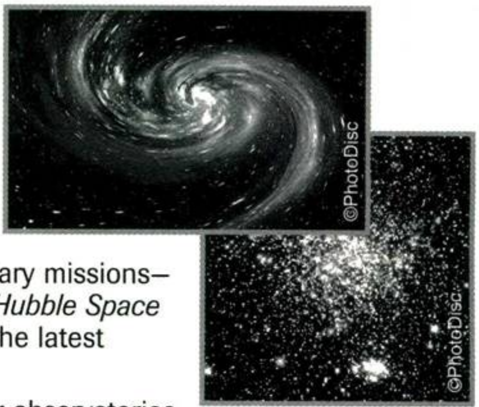
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Explore the Universe Annual 2000 Issue 26/N792/IS003

Astronomy's

2001 Guide to the Sky

JAN

Jupiter's Grand Display

For many, just the mention of the year 2001 brings images of fantastic trips to Jupiter. Arthur C. Clarke and Stanley Kubrick are responsible through their evocative movie, *2001: A Space Odyssey.* Today, there are no manned vehicles traveling to Jupiter – that much remains in the realm of science fiction. Yet spectacular close-up images of the planet from the Voyager and Galileo spacecraft have given us extraordinary views of Jupiter and its moons.

Jupiter is on fine display for everyone this winter, and for no charge. You'll find it high in the southwest among the stars of Taurus the Bull, as Jupiter's apparition winds down following last year's fine show. Jupiter is twelve times the diameter of Earth and the largest planet in the solar system. Its 11.86-year orbit places it opposite the sun in our sky about every 13 months. Jupiter won't reach opposition in 2001. Its last opposition occurred in late November 2000 and the next arrives on January 1, 2002. But for observers of the planet, Jupiter is so big that during quite a few months on either side of opposition the planet puts on a grand display.

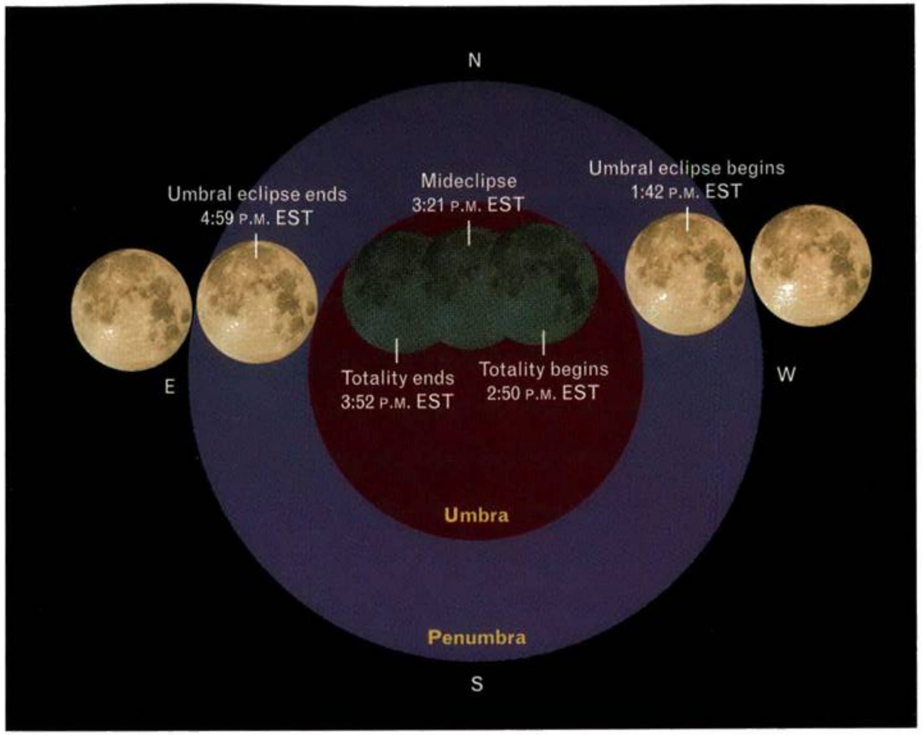
In the first three months of 2001, Jupiter can be seen from the moment the sky becomes dark. In January you'll find it between the lovely Seven Sisters of the Pleiades and the "V"-shaped Hyades. It's the brightest object in the night sky aside from the moon and Venus and lies high in the southeast at sunset shining at magnitude –2.7.

Almost any telescope will show at least some features on Jupiter's face. And steadily held binoculars will reveal four of its moons. The Galilean moons, Io, Europa, Ganymede, and Callisto, perform a ritual dance each night. The swiftest moon is Io, taking a mere 1.8 days to complete one orbit. Callisto takes a little more than two weeks. Every time a moon passes in front of or behind Jupiter, a transit or occultation occurs — such events happen almost nightly and can be seen in 60mm scopes.

John Chumack/Cover photo by Fred Espenak and Ken Bertin

The cloud bands on Jupiter can be observed from Earth with a moderate-sized telescope.

Similar scopes show the principal belts of Jupiter's atmosphere. Jupiter's



For the second year in a row, January plays host to a total lunar eclipse. Benjamin Gomes-Casseres

rapid rotation carries atmospheric features past us similar to watching a slow horse race from a grandstand. The entire planet's visible face rotates in less than 10 hours. Careful observes will notice a change of position of prominent features within 15 to 20 minutes. In reality, the cloud features on Jupiter move at hundreds and thousands of miles per hour.

As each month passes, the planet appears farther west in the sky, along with the attendant stars of Taurus. By the time March comes around, Jupiter hangs high in the west at sundown. A lovely crescent moon passes 3° southeast of Jupiter on March 29. A month later, on April 26, Jupiter hangs lower in the sky, while a 4-day-old moon lies 6° east of the planet in a lovely setting of a late dusky spring sky. By the end of April it shines at magnitude –2.0. Jupiter quickly succumbs to the sun's bright glow during May and passes on the far side of our star (superior conjunction) on June 14. The planet returns to the morning sky in early July and moves into Gemini, spending the rest of the year there as it approaches its next opposition early in 2002.

The Moon's Disappearing Act

The 21st century gets off to a great start with a total eclipse of the moon on the night of January 9/10. For more than 5 hours, the full moon traverses the northern half of Earth's shadow. And for a full hour in the middle, the moon lies completely within the darkest part of the shadow, known as the umbra.

Unlike last January's total lunar eclipse, the favored locations for viewing the 2001 eclipse lie in the Eastern Hemisphere. Essentially everyone with a clear sky in Europe, Asia, and Africa will witness the entire five-hour show.

During totality, the moon takes on an eerie reddish cast. This ruddy glow is actually sunlight that has passed through Earth's atmosphere. The air refracts, or bends, the sunlight into our planet's shadow. It appears reddish because all the blue light has been scattered out, leaving the red (it's the same reason why sunrises and sunsets appear red).

The eastern parts of North and South America don't fare as well — the eclipse has already begun by the time the moon rises. Those in eastern Canada have the chance to view at least some of totality, while those in the northeastern United States and eastern Brazil will see just the concluding partial phases.

After the moon leaves Earth's shadow and climbs high in the sky, it will cast a brighter light than in many years. Remember the hype back in December 1999 when rumors circulated that the full moon was the brightest in more than a century? It wasn't true. And the full moon of January 9/10, 2001, puts the 1999 moon to shame.

This moon triumphs because the moon and Earth now lie closer to the sun, so more sunlight reaches the moon, and the moon lies closer to Earth, reflecting more sunlight back to us. Yet the most important reason has to do with the "opposition effect." Whenever the moon lies directly opposite the sun in our sky, it looks brighter. At most full moons, our satellite passes a few degrees away from this favored location. But as this night's eclipse attests, the moon lies extremely close to the exact opposition point, making it especially bright.

S	M	T	W	T	F	S
	1	◑	3	4	5	6
7	8	●	10	11	12	13
14	15	◐	17	18	19	20
21	22	23	○	25	26	27
28	29	30	31			

EST

3 Quadrantid meteor shower peaks

5 **8 P.M.**
The moon passes 2° south of Saturn

6 **9 A.M.**
The moon passes 3° south of Jupiter

9 **3 P.M.**
Total lunar eclipse

17 **1 A.M.**
Venus is at greatest eastern elongation (47°, evening)

22 **1 P.M.**
Mercury passes 0.4° south of Uranus (evening)

25 **10 P.M.**
The moon passes 3° south of Mercury

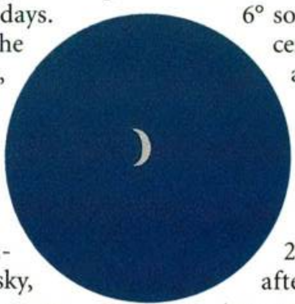
28 **8 A.M.**
Mercury is at greatest eastern elongation (18°, evening)
9 A.M.
The moon passes 6° south of Venus

Events in **red** are ones you won't want to miss. All times in the calendar are eastern time. "Morning" or "evening" at the end of a listing denotes that the event appears before sunrise or after sunset, respectively.

FEB

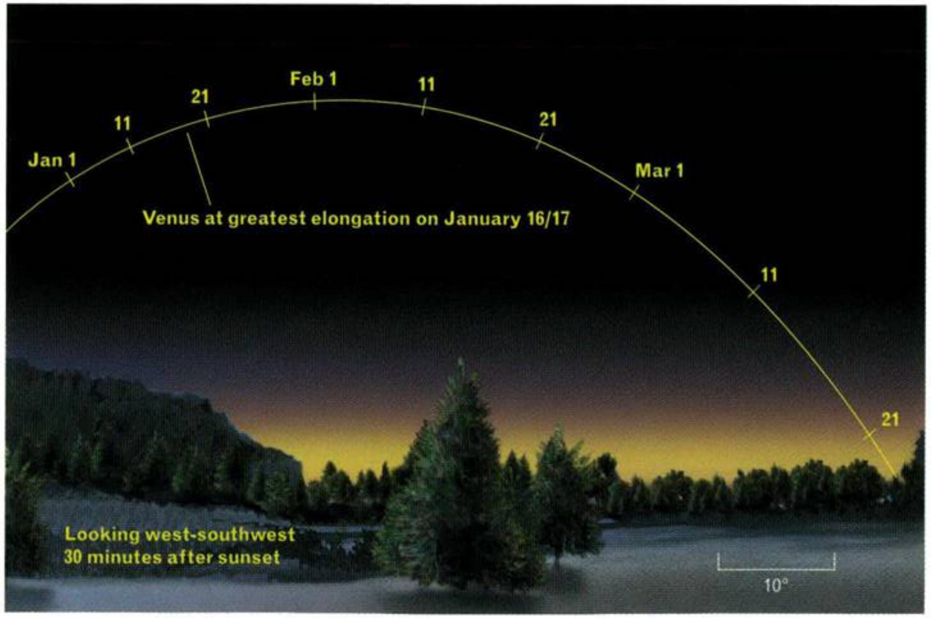
The Evening Star

On your drive home from work this winter, you will undoubtedly notice a brilliant object in the southwest after dark. Venus, the evening star, has returned. It reaches greatest brilliancy at magnitude –4.6 on February 21/22. Venus will attract attention like no other planet in the sky for most of the winter and spring of 2001.


Edwin Faughn

Venus orbits the sun every 224 days and lies inside Earth's orbit. Having a smaller orbit than Earth means Venus moves around the sun at a faster clip, overtaking Earth every 584 days. After rounding the sun on the far side from our viewpoint, Venus plays catch up with Earth and grows in apparent size and brightness. Its combined motion with ours carries it farther in angular distance from the sun, dramatically placing it in a dark sky, and changing its shape as it moves from fully illuminated at superior conjunction to a crescent as it approaches inferior conjunction.

Following the changing face proves fascinating and quite easy for owners of small scopes. By the time Venus lies farthest east of the sun on January 17 (47° from the sun), it takes on the appearance of a first quarter moon, exactly 50 percent illuminated. Our own moon passes 6° south of Venus as a slim crescent on January 28. Venus sets a full four hours after the sun. The phase of Venus shrinks rapidly over the following few weeks, reaching a slim 25-percent-illuminated crescent by February 24 and setting three hours after the sun. During the first two weeks of March, Venus falls rapidly in altitude and dims toward magnitude –4.0. During the following week, it becomes lost in the twilight glow before passing between Earth and the sun on March 29/30. Venus enters the morning sky in April, reaching greatest elongation west of the sun on June 8. It will be in conjunction with Saturn on July 15 and with Jupiter on August 5/6.



Although Venus is roughly the same size as Earth, its surface is completely obscured by a thick cloak of clouds. This reflective blanket ensures the brilliance of Venus. The amount of light a planet reflects is called its albedo — and Venus has a high albedo, reflecting 65 percent of the sunlight that reaches it compared with Earth's 37 percent. Little detail is visible through a telescope. Only radar can penetrate the thick cloud decks, as happened in 1994 when the Magellan spacecraft completed a detailed map of the entire globe from orbit around our evening star.

Exploring the Winter Sky

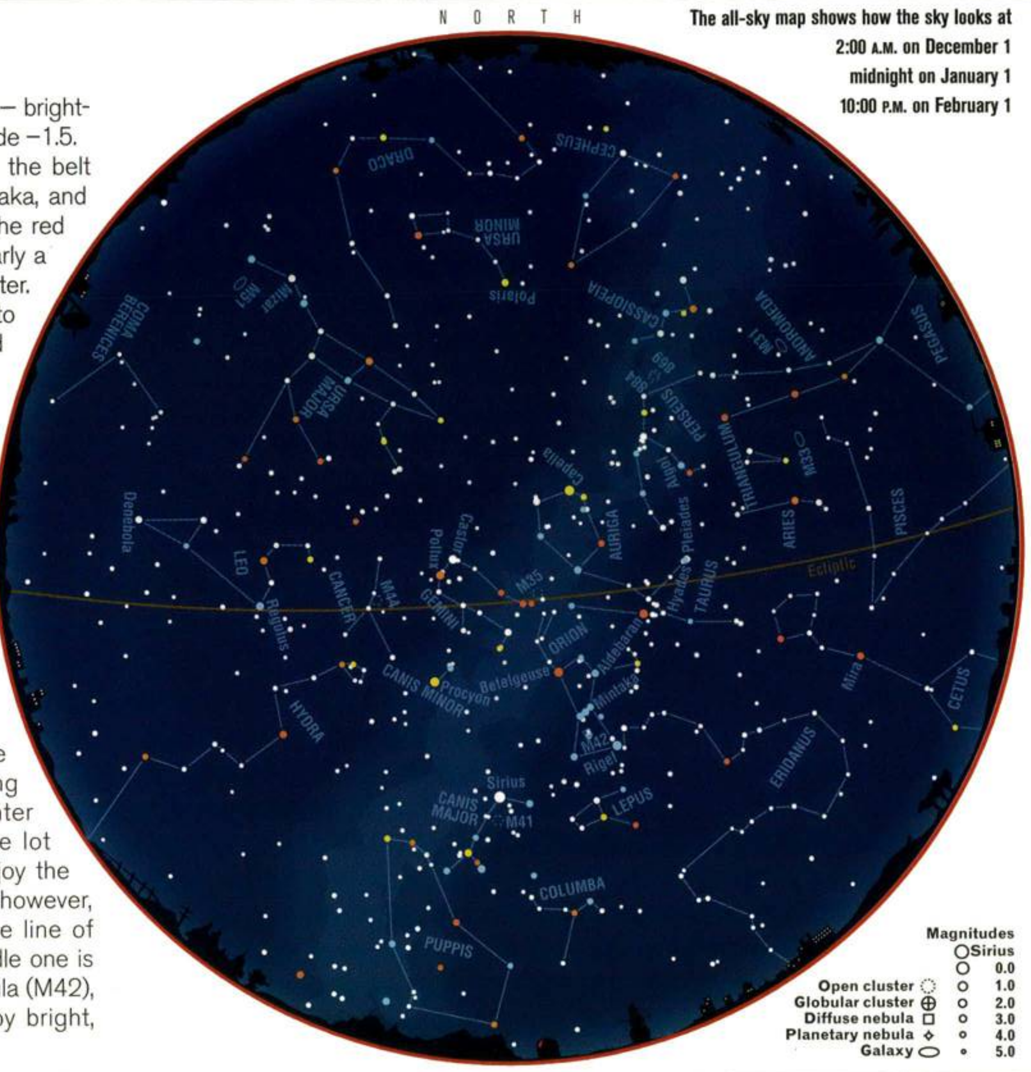
Have you ever become lost in an unfamiliar city or state? Chances are you used two things to get around – a map and some signposts. In much the same way, these two items can help you find your way around the sky in any season. Fortunately, in addition to our seasonal sky charts, there are two major signposts provided for us in the sky. Each seasonal description will talk about the first one – the Big Dipper: a group of seven bright stars in the constellation Ursa Major.

Winter sees the Big Dipper in the northeastern sky, with its triple-starred handle pointing toward the horizon and the four-starred bowl standing highest. The entire sky rotates around a point near Polaris, a 2nd-magnitude star found by extending a line from the uppermost pair of stars in the bowl across the sky to the left of the Dipper.

Turn around with your back to the Dipper and you'll be facing the diamond-studded winter sky. The second great signpost in the sky, Orion the Hunter, is central to the brilliant scene. Three closely spaced 2nd-magnitude stars in a straight line form the unmistakable belt of Orion. Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its orangish 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left and you cannot miss Sirius the Dog Star – brightest in all the heavens at magnitude –1.5.

Now move perpendicular to the belt from its westernmost star, Mintaka, and find at the upper left of Orion the red supergiant star, Betelgeuse, nearly a thousand times the sun's diameter. Continuing this line brings you to a bright pair of stars, Castor and Pollux. Two lines of fainter stars extend from this pair back toward Orion – these represent Gemini the Twins. At the northeastern corner of this constellation lies the beautiful open star cluster M35.

Above Orion and nearly overhead on winter evenings is brilliant Capella in Auriga. Extending a line through the shoulders of Orion to the east leads you to Procyon in Canis Minor. Once you have these principal stars mastered, using our chart to discover the fainter constellations will be a whole lot easier. Take your time, and enjoy the journey. Before leaving Orion, however, aim a pair of binoculars at the line of stars below the belt – the middle one is actually the glorious Orion Nebula (M42), a stellar nursery illuminated by bright, newly formed stars.


NORTH
DRACO
CEPHEUS
URSA MINOR
Polaris
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
COMA BERENICES
M51
Mizar
URSA MAJOR
PERSEUS
869
884
Algol
TRIANGULUM
M33
Capella
AURIGA
ARIES
PISCES
Denebola
LEO
Regulus
CANCER
M44
Pollux
Castor
GEMINI
M35
Pleiades
Hyades
TAURUS
Ecliptic
Aldebaran
ORION
Betelgeuse
Procyon
CANIS MINOR
Mintaka
M42
Rigel
HYDRA
Mira
CETUS
ERIDANUS
Sirius
CANIS MAJOR
M41
LEPUS
COLUMBA
PUPPIS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on December 1
midnight on January 1
10:00 P.M. on February 1

S	M	T	W	T	F	S
				◑	2	3
4	5	6	7	●	9	10
11	12	13	◐	15	16	17
18	19	20	21	22	○	24
25	26	27	28			

EST

2 **5 A.M.**
The moon passes 2° south of Saturn
5 P.M.
The moon passes 3° south of Jupiter

9 **7 A.M.**
Uranus is in conjunction with the sun

12 **7 P.M.**
Mercury is in inferior conjunction

15 **5 A.M.**
The moon passes 3° north of Mars

20 **6 P.M.**
The moon passes 2° south of Neptune

21 **11 A.M.**
The moon passes 6° south of Mercury
8 P.M.
Venus is at greatest brilliancy (magnitude –4.6)

26 **3 A.M.**
The moon passes 11° south of Venus

MAR

Explore the Maiden's Galaxies

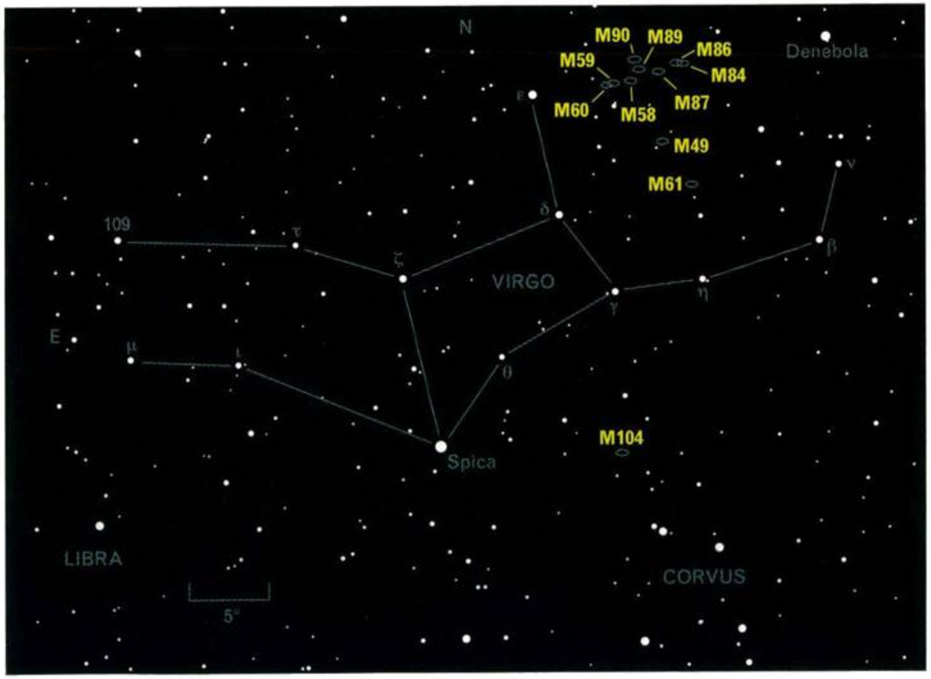
As the bright star clusters and splashy nebulae that delineate the winter Milky Way sink toward the horizon, our gaze opens into the wider universe. Without the interfering dust of the Milky Way to block the view, we can see far beyond the confines of our own galaxy.

Nowhere is this more evident than in the constellation Virgo the Maiden, where the nearest large cluster of galaxies resides. Scan this region with a telescope and you're bound to land on one of these fascinating faint fuzzies.

When the 18th-century astronomer Charles Messier began cataloging nebulous objects, he found nine within Virgo's borders. All turned out to be galaxies. To discover Virgo's treasures on your own, pick a clear, moonless night in spring.

The Sombrero Galaxy, M104, is an 8th-magnitude target in the constellation Virgo. Jason Ware

The heaviest concentration of galaxies resides in the northern part of the constellation, at the heart of the Virgo Cluster. Here you'll find the massive elliptical galaxies M84 and M86, which mark the cluster's center. Just slightly southeast of this pair lies the even bigger M87. With a trillion or more stars and the largest collection of globular star clusters known, M87 puts the Milky Way to shame. It also emits a prodigious amount of radio energy, a consequence of the supermassive black hole astronomers discovered at the galaxy's center. Each of these galaxies glows at 9th magnitude, putting them within easy reach of a backyard telescope.



Yet elliptical galaxies don't have the pizzazz of their spiral cousins. Down in the southern reaches of Virgo lies one of the sky's grandest spirals, the Sombrero Galaxy (M104). This galaxy has a pronounced dust lane that looks a little bit like the brim of a Mexican hat, hence the nickname. The dust lane is conspicuous because the galaxy tilts just 6° to our line of sight. The Sombrero holds an exalted place in the history of astronomy, having been among the first galaxies to have its rotation and redshift measured.

A Grand Gathering

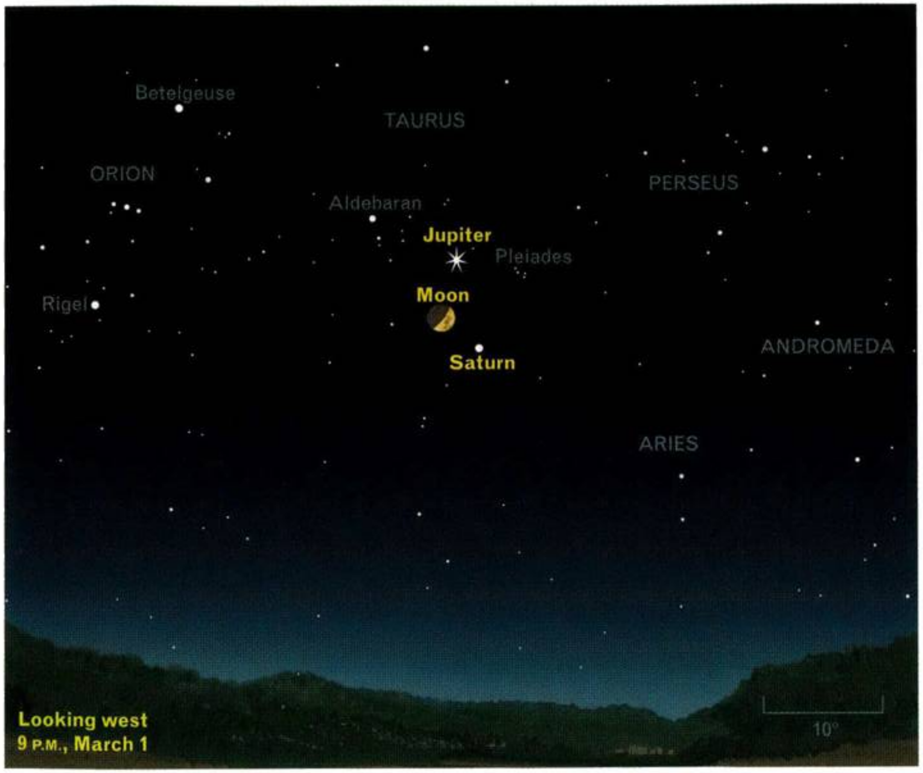
One of nature's more wonderful sights happens whenever the moon appears to pass a bright planet, creating what skywatchers call a conjunction. These events offer a fine opportunity to compare different worlds in a telescope.

It can also help you locate nearby planets or bright stars using the moon as a convenient guide. One beautiful conjunction occurs on March 1.

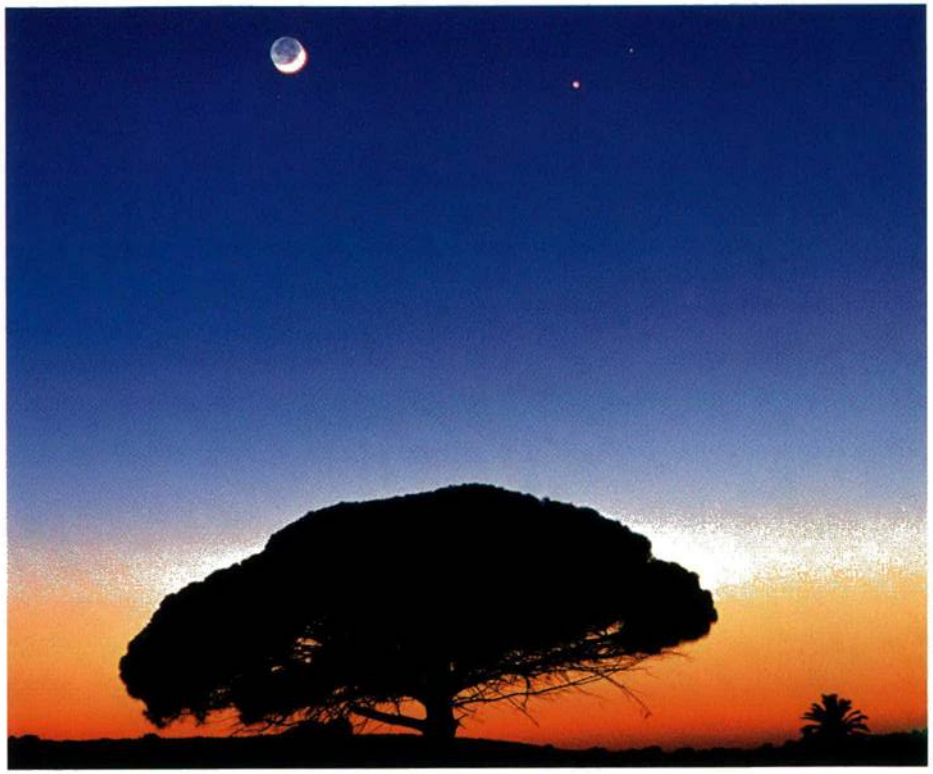
That evening sparkles in part because the moon lies halfway between two bright planets: Jupiter and Saturn. These two gas giants had a conjunction of their own in May 2000. But because they both lie far from the sun, they orbit at a relatively leisurely pace and don't move rapidly across the sky. So even now, nearly a year after their conjunction, the planets remain near one another in Taurus.

Head outside as the sky darkens and you'll immediately notice the moon. On the 1st, it appears as a fat crescent, slightly but noticeably less than halflit. Just above it lies brilliant Jupiter. Shining at magnitude –2.3, you won't mistake it for anything else. (Only Venus appears brighter than Jupiter and it lies much lower in the west, setting by 9 P.M.) Saturn appears below and to the right of the moon. At magnitude 0.2, it pales in comparison with Jupiter but holds its own against the bright stars of winter.

A telescope won't give you a better view of the conjunction itself — it magnifies too much to show all three objects in one field of view. But a scope will yield a magnificent view of the individual objects — the wind-torn cloudtops of Jupiter and the stunning rings of Saturn. Then examine the moon at the terminator, where sunrise brings mountains and craters into stark relief.



Looking west
9 P.M., March 1



Conjunctions occur when celestial objects appear to lie near to each other from a viewpoint on Earth.

Gianni Tumino and Melania Pluchinotta

S	M	T	W	T	F	S
				1	◑	3
4	5	6	7	8	●	10
11	12	13	14	15	◐	17
18	19	20	21	22	23	○
25	26	27	28	29	30	31

EST

1 **1 P.M.**
The moon passes 2° south of Saturn

2 **4 A.M.**
The moon passes 3° south of Jupiter

4 **9 A.M.**
Mars passes 5° north of Antares (morning)

10 **6 A.M.**
Mercury passes 0.1° north of Uranus (morning)

11 **1 A.M.**
Mercury is at greatest western elongation (27°, morning)

20 **3 A.M.**
The moon passes 2° south of Neptune
9 A.M.
Equinox (northern spring/southern autumn begins)

27 **2 A.M.**
Vesta is in conjunction with the sun

28 **11 P.M.**
The moon passes 1.7° south of Saturn

29 **4 P.M.**
The moon passes 2° south of Jupiter

APR

A Rogue Returns

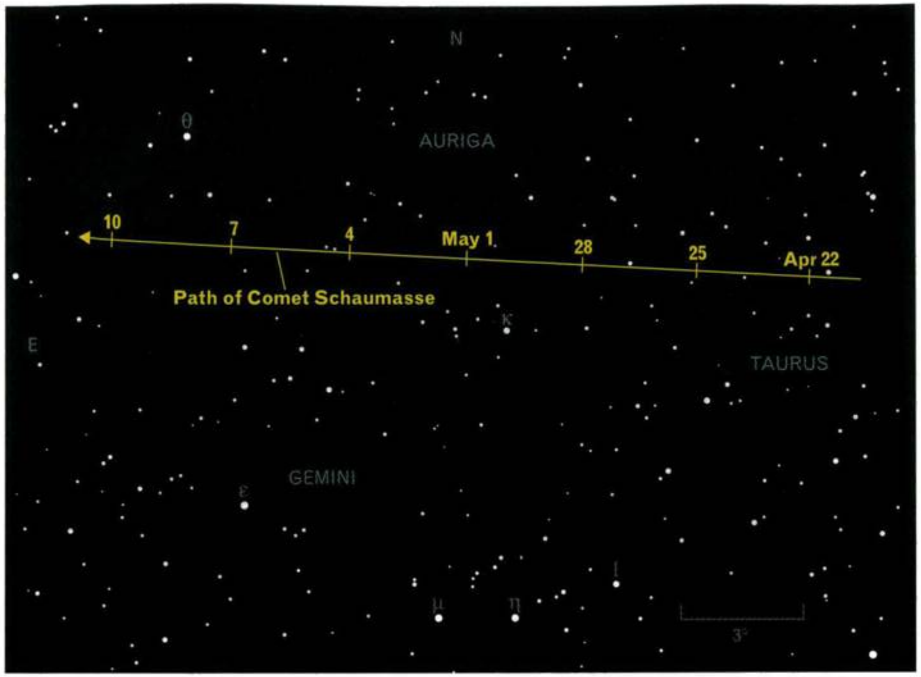
The brightest comet of 2001 will likely go by the name of Schaumasse. Glowing at 10th magnitude when it peaks in late April and early May, Schaumasse won't invite any favorable comparisons to the best comets of the past decade: 1996's Hyakutake and 1997's Hale-Bopp. It probably won't even live up to last year's Comet LINEAR. But Schaumasse should still put on a good show for backyard observers with modest telescopes. And who knows, perhaps 2001 will be graced with a bright, unexpected visitor just as 1996 and 1997 were.

The best time to hunt down Schaumasse will be in the last week of April. (In the first week of May a gibbous moon interferes with the view.) The comet then lies closest to both the sun and Earth, coming within 112 million miles of the sun and 140 million miles of Earth. The relative proximity to the sun warms the comet's nucleus, causing the ices there to turn directly to gas and release lots of gas and dust in the process. It is this cloud of gas and dust — not the tiny nucleus itself — that we see as the comet.

Schaumasse remains in the evening sky throughout this apparition. You can find it roughly 30° high, or one-third of the way from the horizon to the zenith, in the west as twilight ends. The stars of Gemini and Auriga provide several guide stars to help you locate the comet. Look for a fuzzy object that resembles a distant galaxy or nebula. You can confirm the comet's identity by watching for it to

Michael Stecker

This image of Comet Schaumasse was taken in 1993. Its appearance resembles that of a galaxy.



move. Schaumasse's orbit takes it across Earth's sky fast enough that you should be able to detect its motion over the course of just an hour or two.

In Search of a Young Moon

Ask a backyard observer what his or her favorite telescopic target is and you'll get a wide range of answers. Some people like to track down faint galaxies, others enjoy the clusters and nebulae that populate the Milky Way, while still others prefer the ever-changing views offered by our solar system's varied planets and attendant satellites.

But most observers agree on at least one thing: Few naked-eye sights surpass the beauty of a slender crescent moon suspended against the orange, red, and purple colors of a twilight sky. The best time of year to spot such a crescent in the evening sky comes in early spring. That's when the ecliptic — the apparent path of the sun across the sky, which the moon and planets also follow closely — makes a steep angle to the western horizon after sunset. Thus the angular separation of the moon from the sun translates into altitude above the horizon.

This year offers two nice opportunities to search for a young moon. The first comes on the evening of March 25, when the moon will be barely one-day old. New moon arrives at 8:21 P.M. EST on the 24th, so less than 24 hours elapse in eastern North America by the time the sun sets the following day. Spotting a moon this young requires a lot of effort and a little luck. Find an observing site with an unobstructed view all the way down to the western horizon — this includes buildings, hills, and nearby trees. And make sure to start searching for the moon no more than 20 minutes after the sun goes down. Use binoculars to spot it if you must, but once you find it set them aside and see if you can glimpse the moon without optical aid.

If cloudy skies ruined your chance to view March's baby moon, a second opportunity arrives one lunar month later. With new moon coming at 11:26 A.M. EDT on April 23, the young moon on the 24th will be several hours older and therefore a wee bit fatter than it was the month before. Still, spotting such a young moon isn't easy. If you just can't find it so soon after its new phase, wait a day or two for it to climb higher into a darker sky.

The slender crescent should appear bathed in an eerie glow known as "earthshine." This is sunlight reflected off Earth's clouds and oceans onto the moon. (Earth emits no natural light of its own.) Earthshine gets harder to see as the crescent thickens for the following two reasons. First, the moon's sunlit portion grows fatter and creates more glare. Second, as the moon moves in its orbit around Earth, it sees more of our planet's nightside, and so has less sunlight reflected onto it.

With a clear horizon, you can capture a moon as young as one-day old.

Alan Dyer

S	M	T	W	T	F	S
◐	2	3	4	5	6	●
8	9	10	11	12	13	14
◐	16	17	18	19	20	21
22	○	24	25	26	27	28
29	◑					

EDT

6 **5 P.M.**
Mercury passes 10° south of Venus (morning)

12 **10 P.M.**
The moon passes 1.3° north of Mars

16 **10 A.M.**
Jupiter passes 5° north of Aldebaran (evening)
noon
The moon passes 3° south of Neptune

17 **7 P.M.**
The moon passes 3° south of Uranus

20 **4 P.M.**
The moon passes 10° south of Venus

22 Lyrid meteor shower peaks

23 **5 A.M.**
Mercury is in superior conjunction

25 **noon**
The moon passes 1.4° south of Saturn

26 **9 A.M.**
The moon passes 1.8° south of Jupiter

29 **10 P.M.**
Juno is in conjunction with the sun

MAY

Mercury's Dance with the Giants

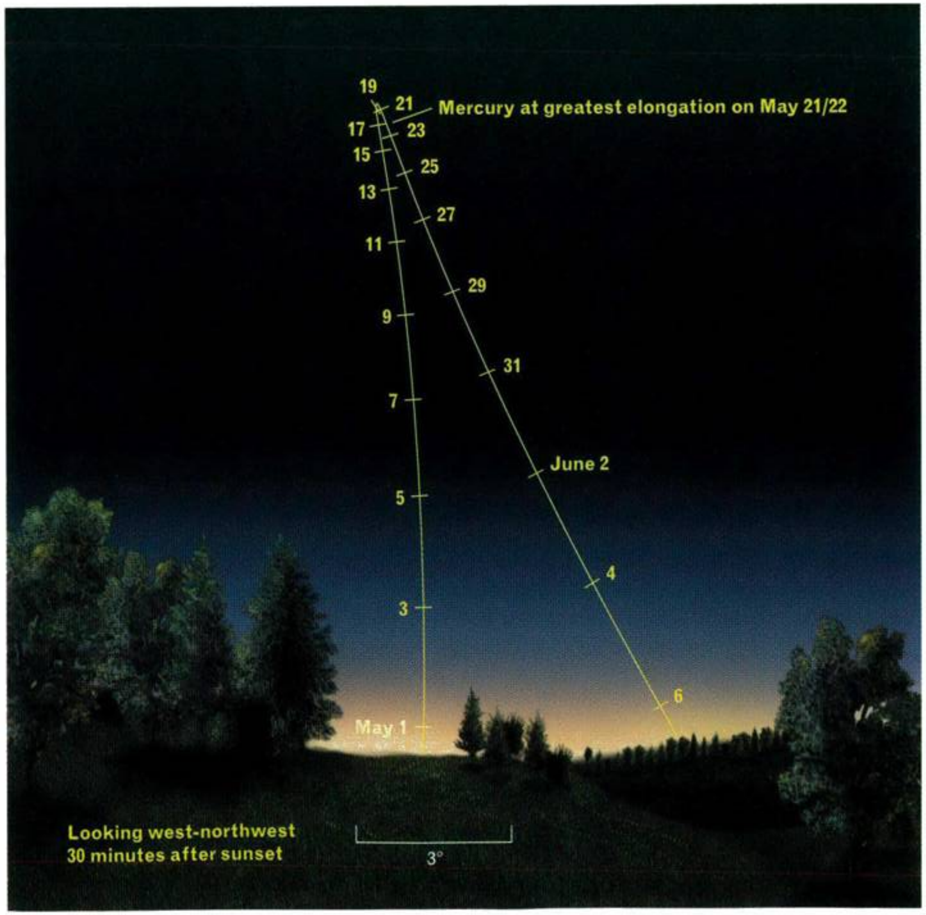
Like an elusive firefly, Mercury darts in and around the fires of the sun, never straying far from the brilliant powerhouse at the center of our solar system. Mercury is often a challenge to view, but this spring we get the best opportunity of the year, as it reaches greatest eastern elongation.

The best time for evening viewing of Mercury in 2001 occurs from May 1 to June 7. Mercury reaches its greatest eastern elongation on May 21/22, when it lies 22° from our star. Mercury changes from a tiny, fully illuminated disk to a larger but less illuminated crescent. It appears brighter when fully lit, but then lies too close to the sun for us to see. As it moves away from the sun it fades quickly.

Try to pick out Mercury on May 1 shortly after sunset, when it shines at magnitude –1.5 while lying just 9° west of the sun. You don't have much time, however, because Mercury sets a mere 50 minutes after sunset.

Things improve rapidly as Mercury begins a dance with the two giant planets of the solar system. On May 6 it passes between Saturn and the Pleiades and lies 4° north of Saturn on the following night. Saturn is a little fainter than Mercury at magnitude 0.1. On the same night Jupiter hangs 12° above the pair and shines at magnitude –2.0.

By May 11 Mercury has moved 18° away from the sun and lingers at a bright magnitude of –0.6. It's closing in on Jupiter to become its brief companion. On May 16 only 3° separate Jupiter and Mercury. Mercury sets nearly 2 hours after the sun in a spectacular grouping among the stars of Taurus the Bull. On the evening of its greatest elongation, Mercury lies midway between the stars that mark the two horns of the bull. A line joining Mercury, Jupiter, and Aldebaran provides a spectacular setting for this Mercury apparition. By June 7 Mercury has dropped in altitude and brightness and becomes a very difficult object, glowing weakly at magnitude 3.



Exploring the Spring Sky

The Big Dipper, our signpost in the sky, swings high overhead during the spring and lies near the center of our chart. This season of rejuvenation encourages us to move outdoors with the milder temperatures, and with it a new set of stars beckons us.

Follow the arc of stars outlining the handle of the Dipper away from the bowl and you will land on brilliant Arcturus. This orangish star dominates the spring sky in the kite-shaped constellation Boötes. Well to the west of Boötes lies Leo the Lion. You can find its brightest star, Regulus, by using the pointers in the Dipper in reverse. Regulus lies at the base of a group of stars shaped like a backward question mark, which represents the head of the lion.

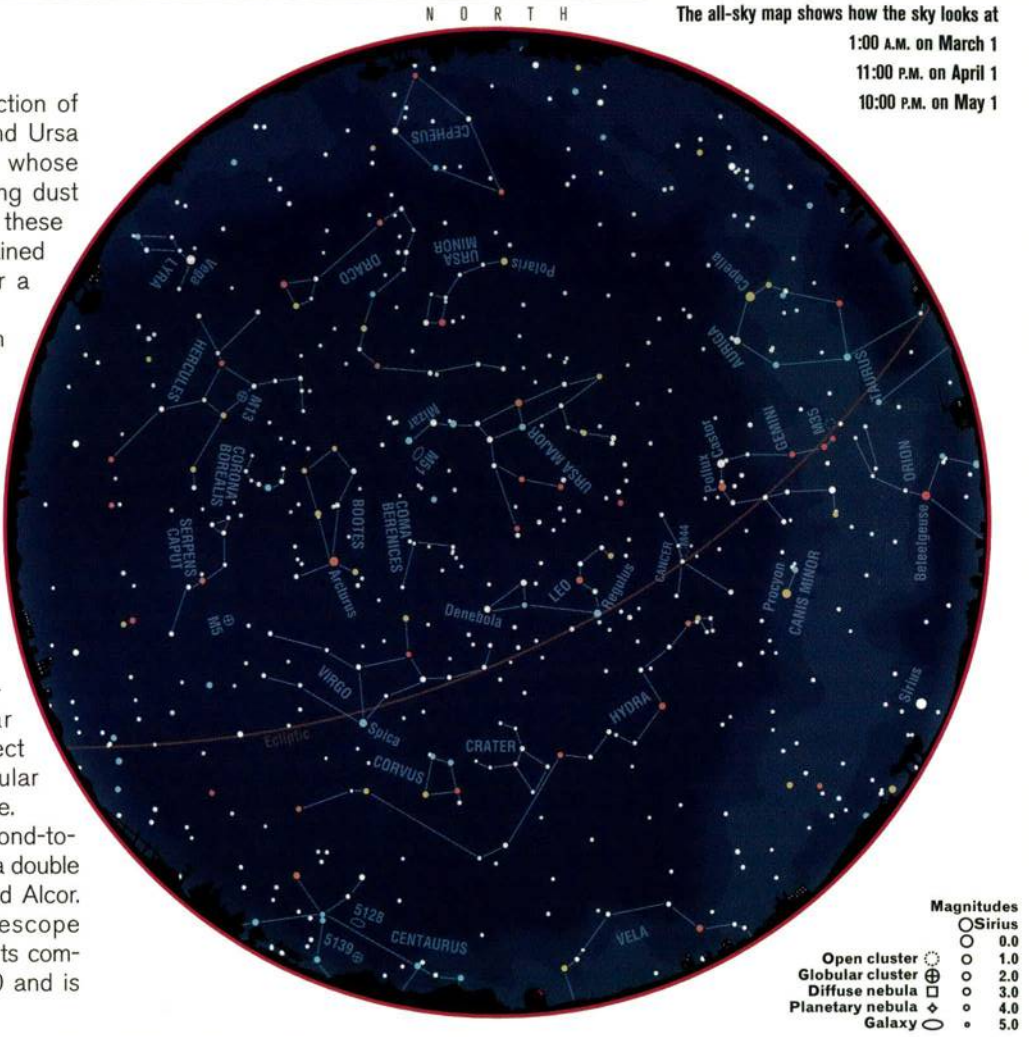
Midway between Regulus and Pollux in Gemini, which is now sinking in the west, is the diminutive group Cancer the Crab. Centered in the group is a hazy patch of light that binoculars reveal as the Beehive star cluster (M44).

To the southeast of Leo is the realm of the galaxies and the constellation Virgo the Maiden. Virgo's brightest star, Spica, shines at magnitude 1.0.

During springtime the Milky Way lies level with the horizon, and it's easy to realize that we are looking out of the plane of our galaxy. In the direction of Virgo, Leo, Coma Berenices, and Ursa Major lie hundreds of galaxies whose light is unhindered by intervening dust in our own galaxy. However, all these galaxies are elusive to an untrained eye and require binoculars or a telescope to be seen.

Boötes lies on the eastern border of this galaxy haven. Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, is a region where no star shines brighter than 2nd magnitude. A semicircle of stars represents Corona Borealis, and adjacent to it is a large region that houses Hercules, the fifth-biggest constellation in the sky. It's here we can find the northern sky's brightest globular cluster, M13. A naked-eye object from a dark site, it is spectacular when viewed through a telescope.

Back at Ursa Major, the second-to-last star in the Dipper's handle is a double star. This pair is called Mizar and Alcor. They lie 0.2° apart, and a telescope shows Mizar itself to be double. Its companion shines at magnitude 4.0 and is 14" from Mizar.


N O R T H
CEPHEUS
URSA MINOR
Polaris
DRACO
LYRA
Vega
HERCULES
M13
CORONA BOREALIS
SERPENS CAPUT
M5
BOOTES
Arcturus
COMA BERENICES
M51
Mizar
URSA MAJOR
LEO
Regulus
Denebola
VIRGO
Spica
Ecliptic
CORVUS
CRATER
HYDRA
CANCER
M44
GEMINI
Pollux
Castor
M35
AURIGA
Capella
TAURUS
ORION
Betelgeuse
Procyon
CANIS MINOR
Sirius
VELA
CENTAURUS
5128
5139
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
1:00 A.M. on March 1
11:00 P.M. on April 1
10:00 P.M. on May 1

S	M	T	W	T	F	S
		1	2	3	4	5
6	●	8	9	10	11	12
13	14	◐	16	17	18	19
20	21	○	23	24	25	26
27	28	◑	30	31		

EDT

4 **2 P.M.**
Venus is at greatest brilliancy (magnitude –4.5)

5 Eta Aquarid meteor shower peaks

10 **3 P.M.**
The moon passes 1.9° north of Mars

12 **6 A.M.**
Mercury passes 8° north of Aldebaran (evening)

13 **8 P.M.**
The moon passes 3° south o Neptune

15 **4 A.M.**
The moon passes 3° south of Uranus

19 **5 A.M.**
The moon passes 4° south of Venus

21 **midnight**
Mercury is at greatest eastern elongation (22°, evening)

24 **3 A.M.**
The moon passes 1.3° south of Jupiter
3 P.M.
The moon passes 3° south of Mercury

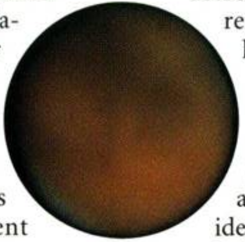
27 **2 P.M.**
Pallas is at opposition

JUN

A Mid-summer Mars Spectacular

On June 13 Mars reaches a glowing opposition when it can be found lying 13° east of Antares, the brightest star in the constellation Scorpius the Scorpion. The word "Antares" means "rival of Mars," but this year Mars easily outshines its challenger, shining at a spectacular magnitude of −2.3.

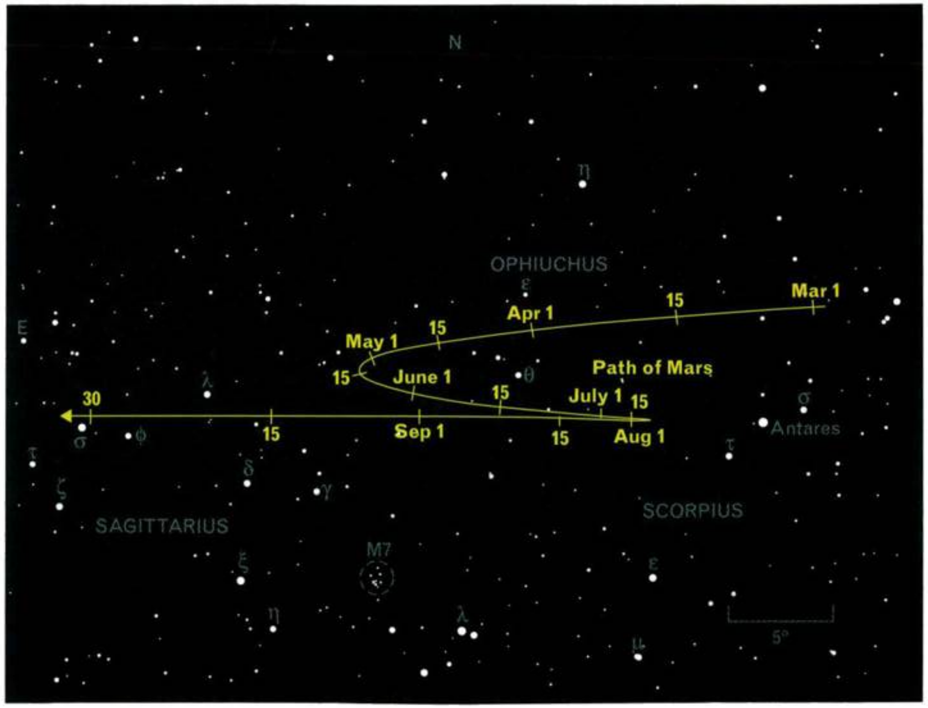
Mars reaches opposition at long intervals: between 764 days and 810 days. Consequently its appearance this year marks a rare opportunity. Opposition occurs while Mars crosses the constellation Ophiuchus, sometimes referred to as the 13th zodiacal constellation. Although Mars will never reach a high altitude for Northern Hemisphere observers, it does come within 42.2 million miles of Earth on June 21, its closest for the year. This distance brings Mars's apparent diameter as seen from Earth to a giant 21".



Donald Parker

Continuing discoveries on the Red Planet in recent years have kept the martian mystery and intrigue alive. While Earth-based telescopes are forever bound to show a limited number of features, the view of Mars generates reminders of wonderful past oppositions and a reflection of how much has changed in the past century or so.

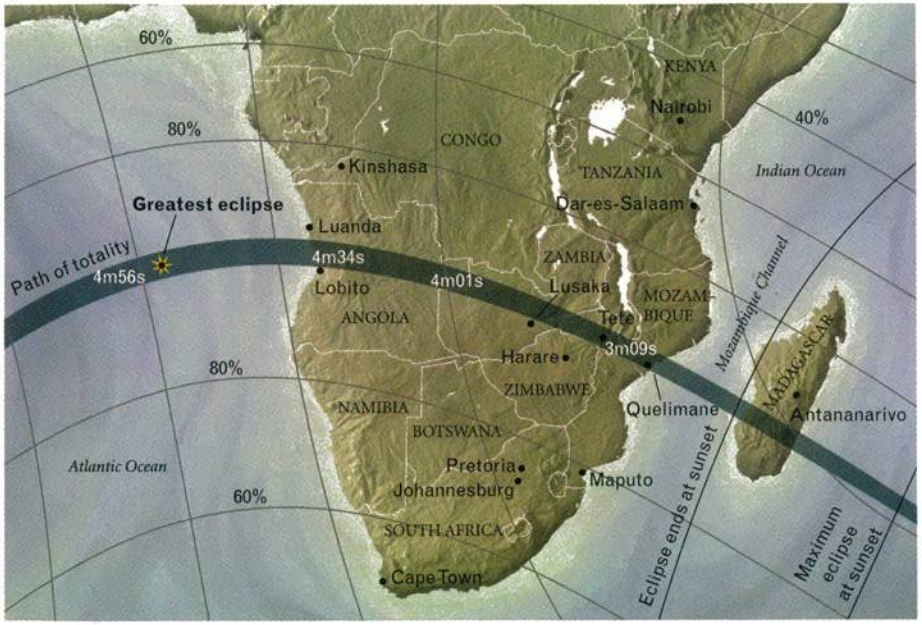
During the opposition of 1887 Italian astronomer Giovanni Schiaparelli recorded more than 40 features he called "canali." Percival Lowell, a diplomat from a wealthy Bostonian family, built his new observatory on Mars Hill in Flagstaff, Arizona, and spent years developing his ideas of an inhabited planet where Schiaparelli's canali became canals, transporting water from the frozen poles to the dry equatorial deserts. Today spacecraft images show Mars for what it really is — a very dry and inhospitable place covered with craters, mountains, and deserts, albeit with strong evidence for underground water. Yet still today people imagine faces on Mars, even though modern images of mountain ranges have placed those fictions into the realm of an overactive, "lowellian" imagination.



Observing the fascinating light and dark features on Mars requires the planet to be at least 10" across. Mars will reach double this size for a whole month beginning June 7. This represents the peak viewing time. However, telescopes of at least 8 inches in aperture can see plenty of detail on the Red Planet as early as March 27, when its diameter passes the 10" threshold. The darkest areas on Mars, such as Syrtis Major and Acidalia Planitia, will be easiest to spot, along with the bright Hellas basin, which is often confused with one of the polar caps. By May 5 Mars reaches 15" in diameter, and it peaks on June 21 at 21" when the Red Planet lies closest to Earth. At this point even a 3-inch scope will reveal the principal markings of the planet's surface.

Mars's path takes it past some interesting objects. The planet spends the early part of the year in Sagittarius and begins retrograde motion, moving westward on May 10 with the Lagoon Nebula (M8) just 2° east. Mars passes due south of the globular cluster NGC 6293 on both June 25 and August 12. It also passes less than 1° south of the bright globular M19 on July 1 and August 6.

Mars shrinks below 10" on October 12. The next opposition comes on August 28, 2003, when Mars will be close to perihelion and reach 25" in diameter.

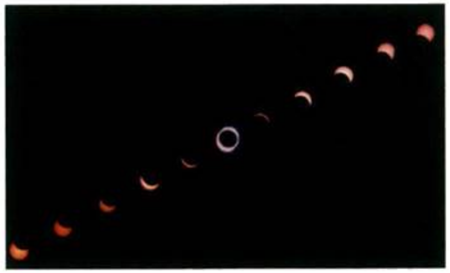


Although today's spacecraft images have replaced regular drawings of the Red Planet done by amateurs over the decades, Mars can throw a few surprises that are often caught by observers with modest telescopes. Mars is a dusty place, and the occasional dust storms appear out of nowhere. Monitoring these storms, which can envelop the entire planet, is important for the longer term understanding of the martian atmosphere, something that future space-farers will have to contend with when they land there, perhaps later this century.

Plunge into Darkness

It's hard to upstage Mars shining at its brightest in 13 years, but the sun and moon conspire to give the Red Planet a run for its money this month. On June 21, the moon passes in front of the sun and blocks it totally from view along a 120-mile-wide slice of southern Africa.

A total solar eclipse will pass over the Atlantic Ocean and Africa in June. H. J. P. Arnold



Those who live in the path of totality or make the effort to travel there should be rewarded with dramatic views and lasting memories.

At maximum eclipse over the South Atlantic, the sun disappears for nearly 5 minutes, the longest for any total eclipse in 9 years. The duration dips as the eclipse track crosses Angola, Zambia, Zimbabwe, and Mozambique but remains above 3 minutes along the center line. After crossing the Mozambique Channel, the moon's shadow makes its final landfall on the exotic island of Madagascar.

Making this eclipse even more tempting are weather prospects rivaling the best in decades. The annual dry season is in full swing across southern Africa and clear skies should be the rule. (At this time of year, only the Sahara Desert offers better prospects for clear skies.) Exquisite views of the sun's corona and prominences await, as does a vast horizon ringed by twilight.

If only the political prospects equaled those for the weather. Much of southern Africa remains embroiled in conflict of one sort or other, providing international travelers with perhaps more adventure than they might like. If you plan on making the trip, it will pay to keep abreast of news on the changing political climate. For more details on viewing the eclipse, see "Diving into Darkest Africa" (August 2000).

S	M	T	W	T	F	S
					1	2
3	4	●	6	7	8	9
10	11	12	◐	14	15	16
17	18	19	20	○	22	23
24	25	26	◑	28	29	30

EDT

4 **8 A.M.**
Pluto is at opposition

6 **3 P.M.**
The moon passes 4° north of Mars

8 **1 A.M.**
Venus is at greatest western elongation (46°, morning)

10 **4 A.M.**
The moon passes 3° south of Neptune

13 **2 P.M.**
Mars is at opposition

14 **9 A.M.**
Jupiter is in conjunction with the sun

16 **9 A.M**
Mercury is in inferior conjunction

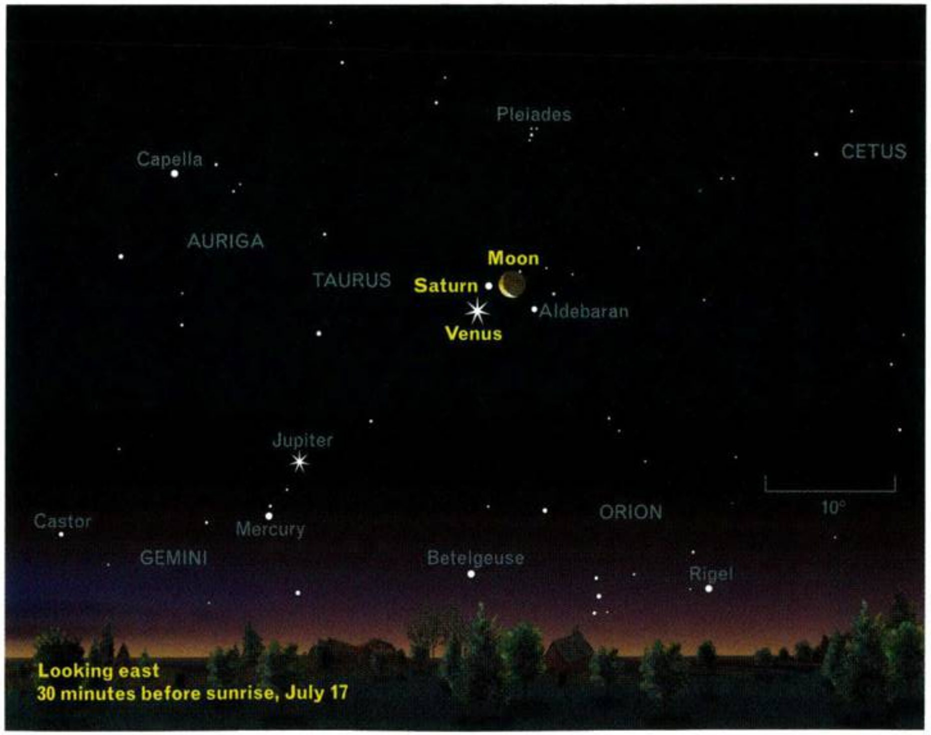
17 **6 P.M.**
The moon passes 1.7° south of Venus

21 **4 A.M.**
Solstice (northern summer/southern winter begins)
8 A.M.
Total solar eclipse (visible in Africa)
7 P.M.
Mars comes closest to Earth

JUL

A Duo of Planetary Pairs

Although conjunctions of the moon with a planet are certainly pretty, they're also pretty common. After all, the moon orbits Earth once each month – and passes each and every planet as it does so. A conjunction between two bright planets, on the other hand, provides both beauty and rarity. With two such conjunctions on tap this month, the stage is set for some celestial fireworks you won't want to pass up.



Looking east
30 minutes before sunrise, July 17

The first event comes in the morning sky on July 12 and 13 when Mercury passes less than 2° south of mighty Jupiter. The two lie low in the east as dawn approaches but should be easy to find because they're bright. At magnitude –1.9, Jupiter serves as a useful guide for locating the 0.0-magnitude Mercury. Despite their proximity in the sky, gaseous Jupiter lies much farther away than rocky Mercury. At the time of their conjunction, Jupiter finds itself 560 million miles from Earth while Mercury is only 86 million miles away.

A more conspicuous conjunction takes place on the morning of July 15. Brilliant Venus then lies less than a degree south of ringed Saturn. There's no mistaking Venus — at magnitude –4.1, it's easily the brightest point of light in the sky. And though Saturn's no slouch at magnitude 0.2, Venus shines 50 times brighter. Venus then lies 92 million miles from Earth, about Earth's distance from the sun (or 1 AU), while Saturn appears to us across more than 900 million miles of space.

The nicest view of all comes two days later, when the moon turns this duo into a trio. The 15-percent-lit crescent hangs just to the right of Saturn in the twilight sky. Later that day, the moon passes in front of Saturn as seen from much of the United States. Although the event occurs in daylight, if you use precation it will be worth the effort to have a telescope set up so you can watch the planet disappear behind the moon's limb.

Spot the First Asteroid

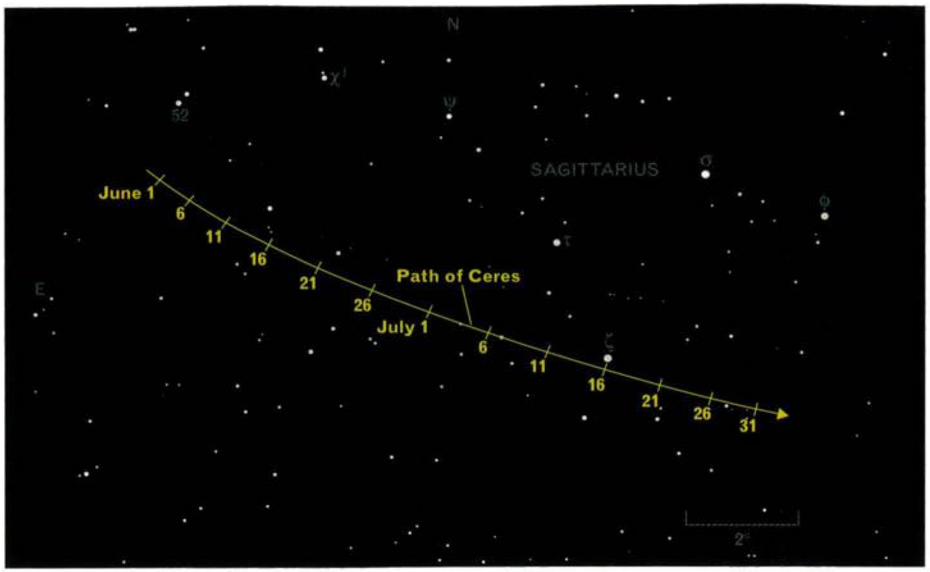
Two centuries have now elapsed since astronomers learned that there is more to our solar system than the sun, planets, moons, and an occasional comet. On January 1, 1801, the Italian observer Giuseppe Piazzi spotted an object that didn't appear on any of his star charts. Returning to the same area of sky during the following weeks, he saw it move rela-

PLANETARY CONJUNCTIONS IN 2001

Date	Planets	Time best seen
January 13	Mercury and Neptune	evening
January 22	Mercury and Uranus	evening
March 10	Mercury and Uranus	morning
April 6	Mercury and Venus	morning
May 7	Mercury and Saturn	evening
May 16	Mercury and Jupiter	evening
July 12	Mercury and Jupiter	morning
July 15	Venus and Saturn	morning
August 5/6	Venus and Jupiter	morning
November 4	Mars and Neptune	evening
November 26	Mars and Uranus	evening

ASTEROIDS IN 2001

Name	Opposition Date	Magnitude	Constellation
6 Hebe	March 26	9.9	Virgo
18 Melpomene	April 23	10.3	Virgo
7 Iris	May 8/9	9.5	Libra
15 Eunomia	May 23	9.6	Lupus
2 Pallas	May 27	9.2	Hercules
1 Ceres	July 7	7.3	Sagittarius
4 Vesta	November 27	6.5	Taurus



tive to the background stars — proving that it belonged to the solar system.

Piazzi had discovered the first asteroid, or minor planet, which was later named Ceres. Today astronomers count more than 10,000 of these rocky objects. Asteroids orbit the sun like planets but are much smaller. Ceres easily ranks as the largest, with a diameter of about 600 miles (compared with Earth's diameter of nearly 8,000 miles). Yet it's big for an asteroid — Ceres contains roughly as much material as all the other asteroids combined.

June and July provide the best opportunities of the year to spy Ceres. It reaches opposition on July 7, when it lies opposite the sun in the sky and appears at its brightest. It glows brighter than magnitude 8.0 throughout these two months, a bit too dim to see with the naked eye but within easy reach of binoculars or a small telescope.

To find Ceres, start with the conspicuous constellation Sagittarius the Archer. Sagittarius lies in the south as midnight approaches and is easy to recognize — look for a group of nine stars in the shape of a teapot. The handle of the teapot, at the eastern end, serves as your starting point. Use the finder chart to zero in on Ceres or wait until mid-July, when the asteroid passes just south of the 3rd-magnitude star Zeta (ζ) Sagittarii.

S	M	T	W	T	F	S
1	2	3	4	●	6	7
8	9	10	11	12	◐	14
15	16	17	18	19	○	21
22	23	24	25	26	◑	28
29	30	31				

EDT

5 **11 A.M**
Partial lunar eclipse

7 **10 A.M.**
The moon passes 3° south of Neptune

3 P.M.
Ceres is at opposition

9 **1 P.M.**
Mercury is at greatest western elongation (21°, morning)

13 **4 A.M.**
Saturn passes 4° north of Aldebaran (morning)

14 **9 P.M.**
Venus passes 3° north of Aldebaran (morning)

15 **1 A.M.**
Venus passes 0.7° south of Saturn (morning)

17 **9 A.M.**
The moon passes 0.6° south of Saturn
2 P.M.
The moon passes 0.3° north of Venus

18 **8 P.M.**
The moon passes 0.2° south of Jupiter

AUG

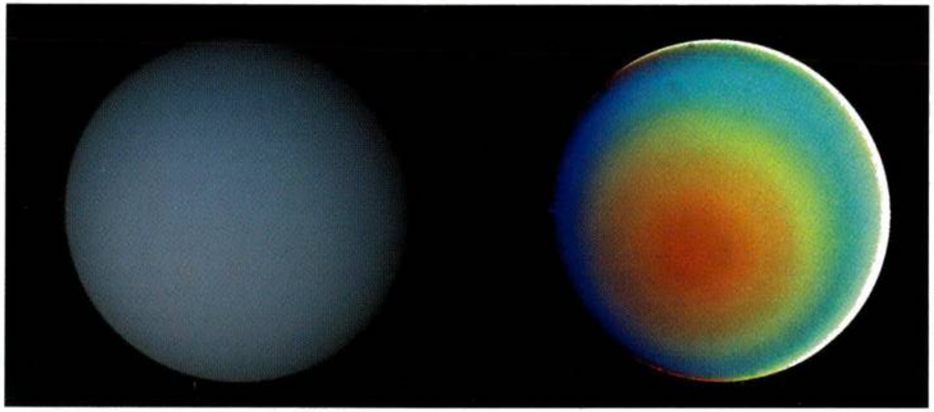
Capture the Distant Gas Giants

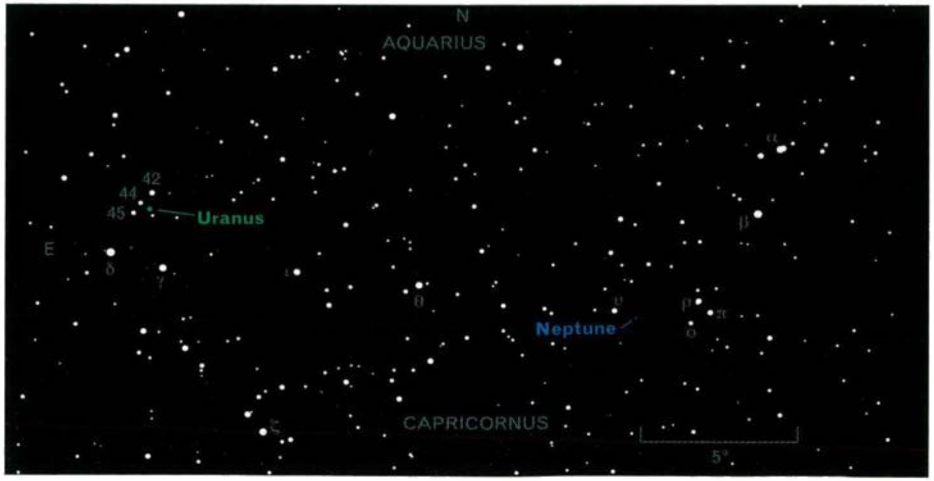
Uranus and Neptune reach opposition a little more than two weeks apart this summer. Both planets lie in Capricornus the Sea Goat, with Neptune being farther west. That means Neptune reaches opposition first, on July 30. On this date it lies 29 astronomical units from Earth, or 29 times the average distance between the sun and Earth. At this distance light from Neptune takes more than four hours to reach us. Neptune shines at magnitude 7.8, bright enough to see in binoculars but difficult to identify among the many faint stars. A telescope at high magnification will show Neptune as a minuscule blue-gray disk about 2" across. Help in identifying Neptune is at hand, however. The 5.1-magnitude star Upsilon (υ) Capricorni lies in the same medium-power field of view on July 21. Watch nightly for a few days either side of this date and the clear motion of Neptune will reveal itself quickly as the planet glides by the star, passing within a few arcminutes at its closest approach.

Neptune by NASA/JPL

Uranus is an easier target. To begin with, it's much closer to Earth than Neptune, lying 18.9 astronomical units away. Uranus is about the same physical size, but its closer proximity makes it brighter at magnitude 5.7. This places Uranus within reach of binoculars and the naked eye from dark-sky locations. Uranus reaches opposition on August 15. At opposition Uranus lies a little less than 2° northwest of the 2.9-magnitude star Delta (δ) Capricorni, the uppermost left star in Capricornus. A week after opposition Uranus lies less than 2° due north of Gamma (γ) Capricorni, making it an easy target.

Telescopes will reveal little of either of these distant globes. But locating the pair and following their daily motions is a challenge that anyone today can attempt.


Uranus by NASA/JPL



Exploring the Summer Sky

The richness of the summer sky is exemplified by the splendor of the Milky Way. Stretching from the northern horizon in Perseus, through the cross-shaped constellation Cygnus overhead, and down to Sagittarius in the south, the Milky Way is packed with riches. These riches include star clusters, nebulae, double stars, and variable stars.

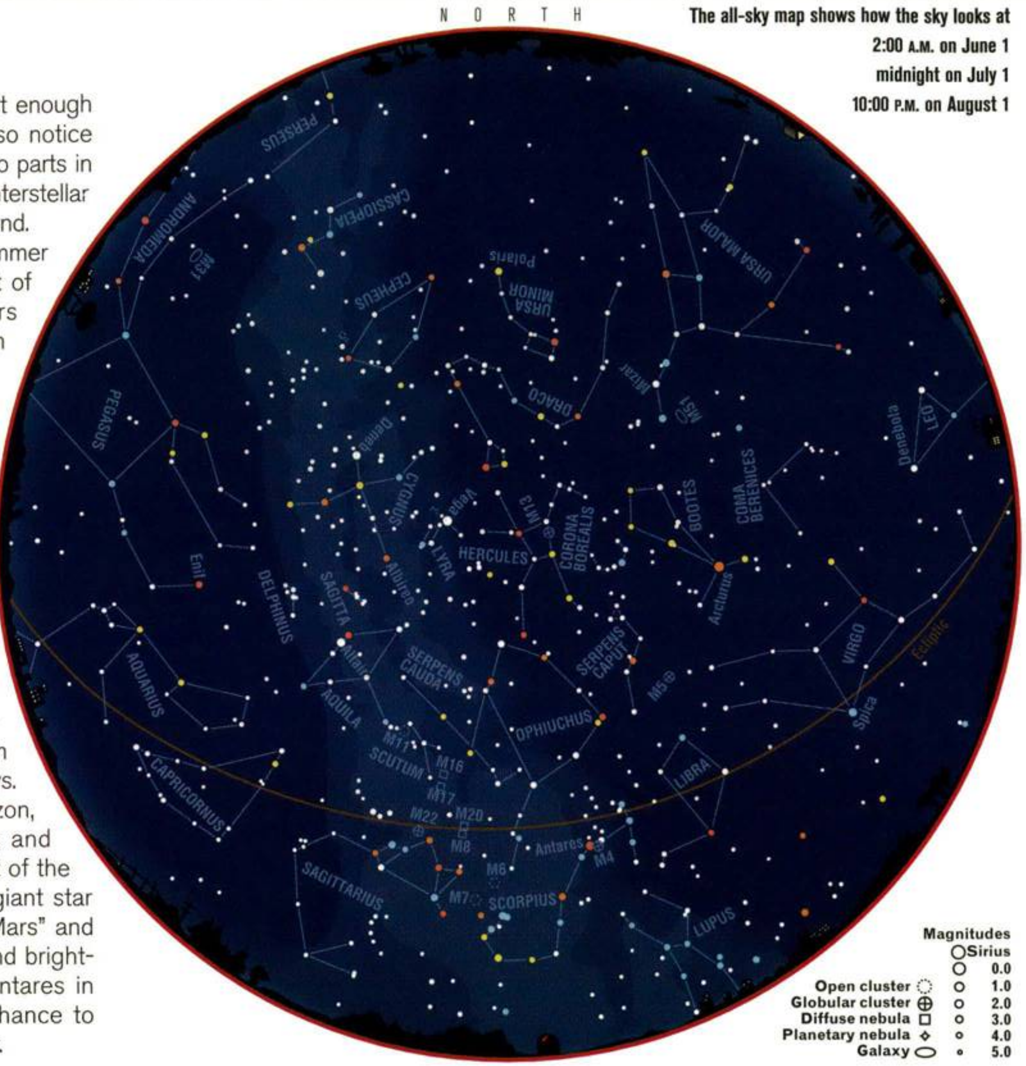
Let's start with the Big Dipper, our perennial stellar signpost, which now lies in the northwest with its handle still pointing toward Arcturus. High overhead and the first star to appear after sunset is Vega in Lyra the Harp. Vega forms one corner of the summer triangle, a familiar asterism of three stars. Near Vega is the famous double-double, Epsilon (ε) Lyrae. Two 5th-magnitude stars lie just over 3' apart and can be split in binoculars. Each of these two stars is also double, but you need a telescope to split them.

To the east of Vega lies the triangle's second star: Deneb in Cygnus the Swan (some see a cross in this pattern). Deneb marks the tail of this graceful bird, the cross represents its outstretched wings, and the base of the cross denotes its head, which is marked by the incomparable double star Albireo – a match of a 3rd-magnitude yellow star and a 5th-magnitude blue star offering the finest color contrast anywhere in the sky. Deneb is a supergiant star pumping out enough light to equal 60,000 suns. Also notice that the Milky Way splits into two parts in Cygnus, a giant rift caused by interstellar dust blocking starlight from beyond.

Altair, the third star of the summer triangle, is the second brightest of the three. Lying 17 light-years away, it's the brightest star in Aquila the Eagle.

Frequently overlooked to the north of Deneb lies the constellation Cepheus the King. Shaped rather like a bishop's hat, the southern corner of Cepheus is marked by a compact triangle of stars including Delta (δ) Cephei. This famous star is the prototype of the Cepheid variable stars used to determine the distances to some of the nearer galaxies. It varies regularly from magnitude 3.6 to 4.3 in 5.37 days.

Hugging the southern horizon, the constellations Sagittarius and Scorpius lie in the thickest part of the Milky Way. Antares is a supergiant star whose name means "rival of Mars" and derives from its similar color and brightness. Mars passes north of Antares in August, providing us with a chance to see how similar the two appear.


NORTH
PERSEUS
ANDROMEDA
M31
CASSIOPEIA
CEPHEUS
Polaris
URSA MINOR
URSA MAJOR
Mizar
M51
DRACO
Deneb
CYGNUS
Vega
LYRA
M13
HERCULES
CORONA BOREALIS
BOOTES
COMA BERENICES
Arcturus
Denebola
LEO
PEGASUS
Enif
DELPHINUS
SAGITTA
Albireo
Altair
AQUILA
SERPENS CAUDA
SERPENS CAPUT
M5
OPHIUCHUS
VIRGO
Spica
Ecliptic
AQUARIUS
CAPRICORNUS
M11
SCUTUM
M16
M17
M22
M20
M8
M6
M7
Antares
M4
SAGITTARIUS
SCORPIUS
LIBRA
LUPUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on June 1
midnight on July 1
10:00 P.M. on August 1

S	M	T	W	T	F	S
			1	2	3	●
5	6	7	8	9	10	11
◐	13	14	15	16	17	○
19	20	21	22	23	24	◑
26	27	28	29	30	31	

EDT

3 **3 P.M.** The moon passes 3° south of Neptune

4 **11 P.M.** The moon passes 3° south of Uranus

5 **8 P.M.** Venus passes 1.2° south of Jupiter (morning)

12 Perseid meteor shower peaks

13 **11 P.M.** The moon passes 0.2° south of Saturn

15 **11 A.M.** Uranus is at opposition
4 P.M. The moon passes 0.4° north of Jupiter

16 **9 A.M.** The moon passes 1.9° north of Venus

22 **9 A.M.** Venus passes 7° south of Pollux (morning)

27 **8 A.M.** The moon passes 5° north of Mars

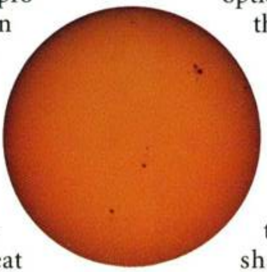
30 **8 P.M.** The moon passes 3° south of Neptune

SEP

Sunny Days

Sunspots still abound on the surface of our star, currently in the latter stages of a peak in solar activity. Ever since Galileo's first telescopic observations of a pockmarked sun, our understanding of our neighborhood star has improved by leaps and bounds. Its observed 11-year periodic cycle of sunspots is well known. Yet much of what powers its turbulent surface is only now being revealed, due in large part to the very successful Solar and Heliospheric Observatory (SOHO) spacecraft.

Daily recording of sunspots is carried on around the clock by a few professional observatories. You can also perform these observations quite easily. Small telescopes are ideal for recording the number of sunspots. Project the sun's image onto a white card by carefully aligning your telescope with the sun. Take great care not to look through the telescope at any time while performing this procedure, since permanent blindness could result. The powerful light and heat from the sun, when focused through any optical device, is not very kind to the delicate retina in your eye. It takes only milliseconds to cause irreparable damage to your vision.


William Grunden

Hold the white card 12 inches or so from the eyepiece and focus the image of the sun — the small dark shadows that you see are the sunspots. A daily record of their

Antoine Gerhardt

Activity on the sun can result in auroral displays. Look north after the last colors of sunset have faded.

positions will reveal the rotation of these sunspots, carried by the 27-day equatorial rotation period of the sun itself.

This year we are in the latter stages of the current 11-year solar cycle, a period when sunspots are very frequent and often large. Their dark appearance is a contrast effect caused by sunspots being 1500–2000 kelvins cooler than the surrounding photosphere, which is around 5800 kelvins.

And if you don't have time to catch activities on the sun using your own telescope, why not check out the most recent images of our star on the World Wide Web, updated every few hours courtesy of the SOHO spacecraft. Click on http://sohowww.nascom.nasa.gov/data/realtime-images.html.

An active sun also bring the opportunity of seeing an aurora. A solar flare or coronal mass ejection sends particles from the sun on the solar wind. If these particles erupt in the direction of Earth, a couple days later they will interact with the upper atmosphere, exciting air molecules and causing them to emit visible radiation — the aurora.

Seeking the Zodiac's Dim Glow

With a name that brings astrology to mind perhaps as much as astronomy, the zodiacal light might not seem like a worthy target for backyard observers. Yet this subtle glow, also known as the "false dawn," certainly has a celestial origin. To find this huge, softly glowing pyramid of whitish-gray light, look toward the east about an hour or two before morning twilight starts. This ethereal glow never fails to impress both the novice and seasoned skygazers.

As the name implies, the zodiacal light can be found along the zodiac, the broad band of sky that encompasses the paths of the planets. From mid-northern latitudes, the zodiacal light is easiest to see on mornings in September and October because the zodiac then makes a steep angle to the eastern horizon. For the same reason, it is relatively easy to see in the west after evening twilight during February and March.

But the subtlety of the zodiacal light means you have to look for it under the right conditions. Observe from a dark location on a haze-free morning when the moon is out of the sky (that means the last two weeks of September and October this year). And use your naked eye — binoculars or a telescope will render the zodiacal light invisible. At its brightest, the light appears slightly brighter than the Milky Way.

The zodiacal light originates close to home. Tiny particles of dust fill the plane of the inner solar system and reflect sunlight in our direction. Most of this dust comes from spent comets or the debris created by colliding asteroids.

The zodiacal light presents a real challenge for observers and requires extremely dark skies. John Cordiale

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S	M	T	W	T	F	S
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●	3	4	5	6	7	8
9	◐	11	12	13	14	15
16	○	18	19	20	21	22
23/30	◑	25	26	27	28	29

EDT

1 **3 A.M.**
The moon passes 3° south of Uranus

10 **9 A.M.**
The moon passes 0.2° north of Saturn

12 **8 A.M.**
The moon passes 1.0° north of Jupiter

15 **3 A.M.**
The moon passes 3° north of Venus

18 **6 P.M.**
Mercury is at greatest eastern elongation (27°, evening)
10 P.M.
The moon passes 8° north of Mercury

20 **4 P.M.**
Mercury passes 0.9° south of Spica (evening)
4 P.M.
Venus passes 0.5° north of Regulus (morning)

22 **7 P.M.**
Equinox (northern autumn/southern spring begins)

24 **9 P.M.**
The moon passes 2° north of Mars

27 **1 A.M.**
The moon passes 3° south of Neptune

28 **7 A.M.**
The moon passes 3° south of Uranus

OCT

Grabbing the Bull by Its Horns

As the nights grow longer and colder, the familiar star patterns of winter begin to reappear in the evening sky. Among the first of these to gain prominence is Taurus the Bull, a conspicuous group dominated by the ruddy 1st-magnitude star Aldebaran, which represents the eye of the bull.

But to a deep-sky observer, Taurus is best known as home to some of the best star clusters and nebulae in the sky. Every discussion of Taurus begins with its two standout open clusters: the Hyades and Pleiades. The Hyades is one of the closest clusters to Earth and covers a large area of sky. That's its biggest drawback — it's so large that no telescope does it justice. Still, spend some time scanning it for double stars, there are plenty to keep double-star aficionados happy. The cluster itself lies about 150 light-years away. Aldebaran — though it may appear to belong to the cluster — lies only half as far away.

The Crab Nebula (M1) was the first object that Charles Messier cataloged. Bill Iburg

The Pleiades (M45) lies half again as far away as the Hyades and benefits from the added distance. This cluster, though it spreads across nearly 2°, is compact enough to show nicely in binoculars or a rich-field telescope. To the naked eye, the six brightest stars form a conspicuous dipper shape. Dozens more come into view with any optical aid. Subtle nebulosity infuses the cluster, but the gas and dust are not remnants of the cluster's formation. Instead, the nebulosity belongs to a cloud that the cluster happens to be passing through.

Perhaps the most intriguing object to call Taurus home is the Crab Nebula (M1). This smudge of nebulosity, located about 1° northwest of the bright star Zeta (ζ) Tauri, is the remains of a massive star that exploded. This supernova explosion, seen on Earth in the year 1054, launched several suns' worth of heavy elements into the interstellar medium that will one day be incorporated into new generations of stars and, perhaps, planets.

The Children of Comet Halley

It should come as no surprise that one of the more consistent showers, the Orionids of October, traces its origin to that most reliable of all comets: Halley. Meteors, or "shooting stars" as they are sometimes called, are actually tiny bits of cosmic dust that burn up from friction when they hit Earth's upper atmosphere.

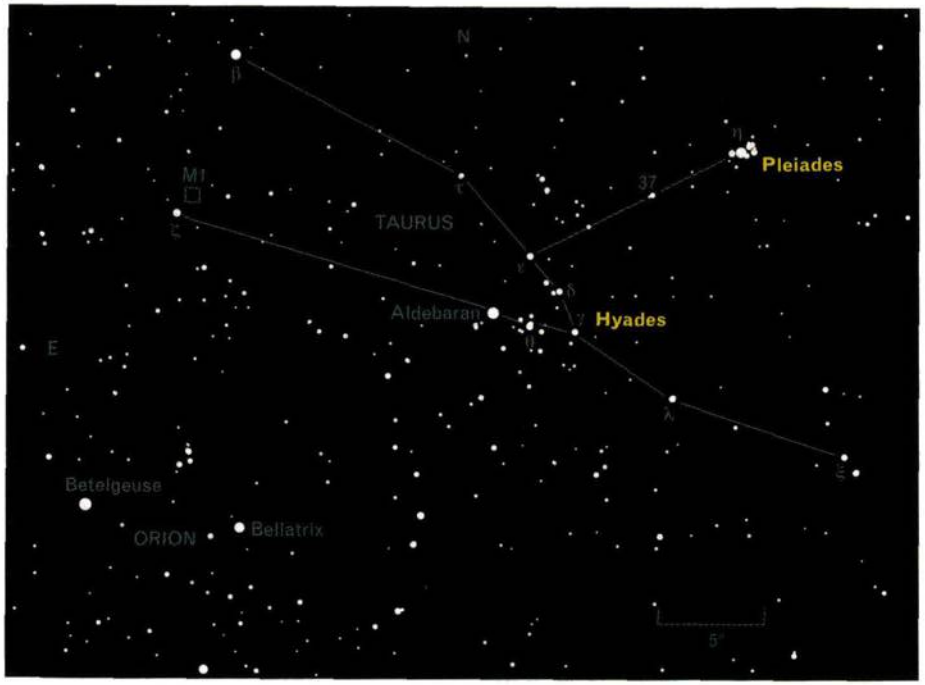
The Pleiades star cluster, also known as the Seven Sisters, is a beautiful naked-eye sight in Taurus. Michael Stecker

Each time Comet Halley passes close to the sun (it last graced the inner solar system in 1986), the sun's heat warms the comet's nucleus, causing the ices there vaporize and releasing gas and dust. This dust forms the graceful, arching tail of the comet and eventually spreads out along the comet's entire orbit. Each October Earth runs into this stream of cometary debris, giving us the meteor shower. (We also hit Comet Halley's stream again in May, giving us the Eta Aquarid meteor shower.)

This year the Orionid shower peaks on the night of October 21/22, when the moon is a waxing crescent. That's good news because the moon will set well before the prime viewing hours after midnight. You can expect to see between 10 and 20 meteors per hour before dawn on the 22nd. As with any meteor shower,

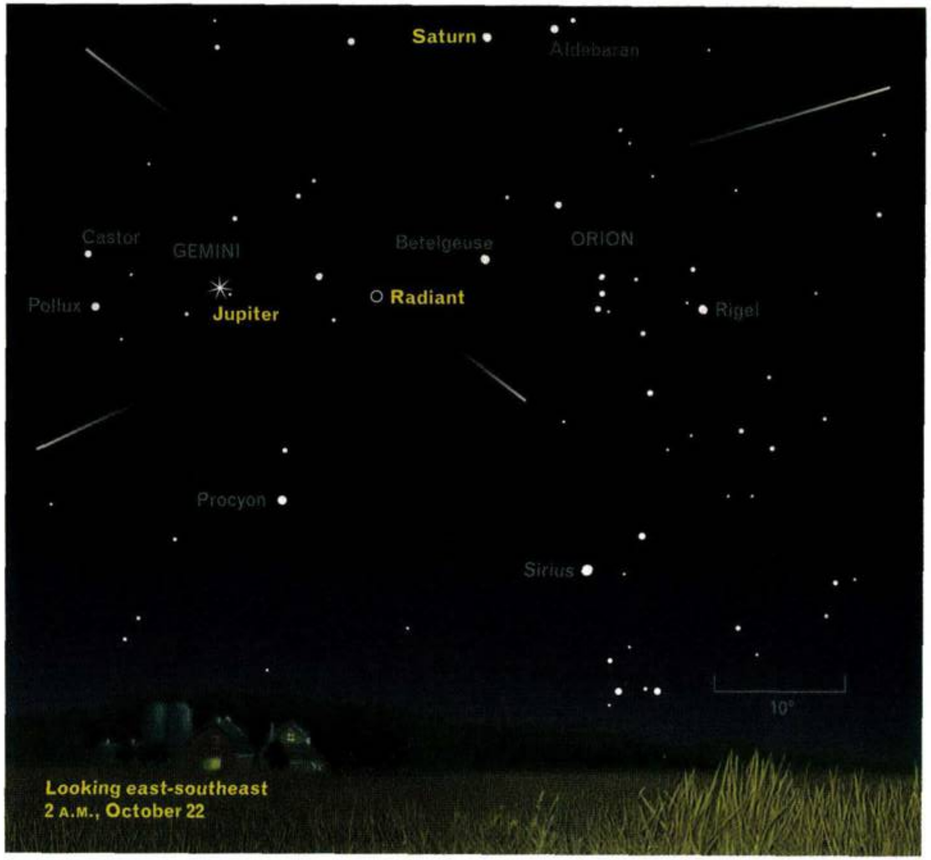
METEOR SHOWERS FOR 2001

Name	Peak Date	Moon's phase	Prospects
Quadrantids	January 3	First quarter	Good
Lyrids	April 21/22	New	Excellent
Eta Aquarids	May 5	Full	Poor
Perseids	August 12	Last quarter	Fair
Orionids	October 21	Waxing crescent	Good
Leonids	November 17	New	Excellent
Geminids	December 13	New	Excellent


N
E
β
M1
ζ
TAURUS
τ
ε
δ
γ
θ
Aldebaran
Hyades
37
η
Pleiades
λ
ξ
Betelgeuse
ORION
Bellatrix
5°

you'll see more if you observe from a rural area where artificial lights are rare. Dress warmly for the chilly October nights and bring along a thermos of hot coffee, tea, or chocolate. Meteor watching is also a great activity in which campers in the wilderness can participate.

The most outstanding visual aspect of the Orionids is their speed: They ram into Earth's atmosphere at 41 miles per second. That's among the fastest for any meteor shower, so expect the streaks to blaze quickly across the sky and a good percentage to leave persistent trains.


Saturn
Aldebaran
Castor
GEMINI
Pollux
Jupiter
Betelgeuse
Radiant
ORION
Rigel
Procyon
Sirius
10°

Looking east-southeast
2 A.M., October 22

S	M	T	W	T	F	S
	1	●	3	4	5	6
7	8	9	◐	11	12	13
14	15	○	17	18	19	20
21	22	◑	24	25	26	27
28	29	30	31			

EDT

7 **3 P.M.**
The moon passes 0.5° north of Saturn

9 **8 P.M.**
The moon passes 1.4° north of Jupiter

13 **10 P.M.**
Mercury is in inferior conjunction

14 **10 P.M.**
The moon passes 4° north of Venus

21 Orionid meteor shower peaks

23 **4 P.M.**
The moon passes 0.1° south of Mars

24 **8 A.M.**
The moon passes 3° south of Neptune

25 **1 P.M.**
The moon passes 3° south of Uranus

29 **noon**
Mercury is at greatest western elongation (19°, morning)

NOV

Are the Leonids Back?

This year could be another bumper year for Leonid meteors. The 1999 predictions of a Leonid meteor storm proved remarkably accurate – for a brief period over the Middle East and Europe, hundreds of meteors streaked across the sky in minutes.

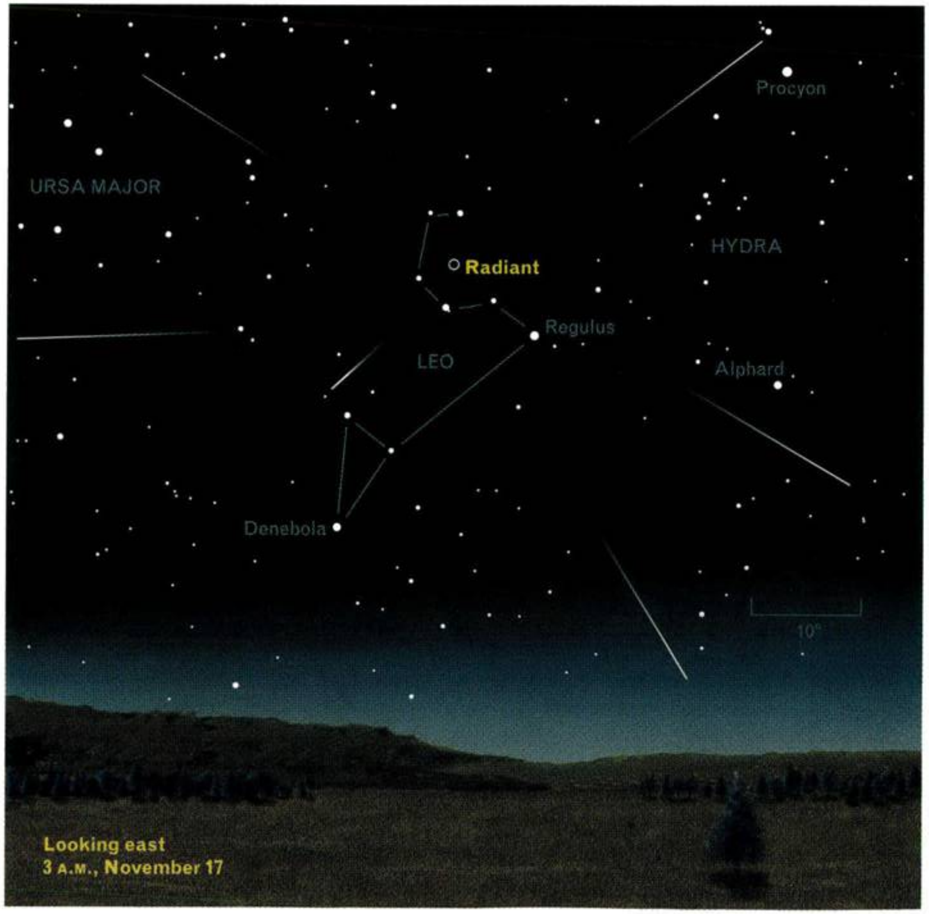
Those same predictive techniques are indicating a storm of significant magnitude on November 17/18. Unlike the event in 2000, which was severly affected by moonlight, the moon cooperates this year with a new phase occurring on November 15.

Although the 1999 storm didn't reach the levels of the 1966 storm, it was proof that predicting storms based on the expected location of leftover debris from previous apparitions of the comet actually worked.

Predictions for 2001 show Earth plowing through debris from the 1866 return of Comet Tempel-Tuttle, the parent comet of the Leonid stream. The timing puts the main event late on November 18 and visible from East Asia, Australia, and the western Pacific. An earlier, smaller peak will be visible from the Americas as Earth brushes the outer debris regions from the 1767 appearance.

The Leonids produce storms every 33 years — because Comet Tempel-Tuttle completes one orbit around the sun every 33 years. Each time the comet passes the warmth of the inner solar system, outgassing from its nucleus generates a new trail of dust. The Leonid meteoroid stream is a young stream and has not yet dispersed. The comet is still active, and the narrow regions of the trails it leaves in its wake contain a relatively high density of meteoroids. Because the trails are narrow, Earth passes through them in minutes — producing a sudden and dramatic increase in numbers for those regions of the planet lucky enough to be in darkness at the time.

If predictions turn out to be accurate, this November's event promises to be one of the best Leonid storms. Astronomers around the globe will be watching with bated breath.



Looking east
3 A.M., November 17

Exploring the Autumn Sky

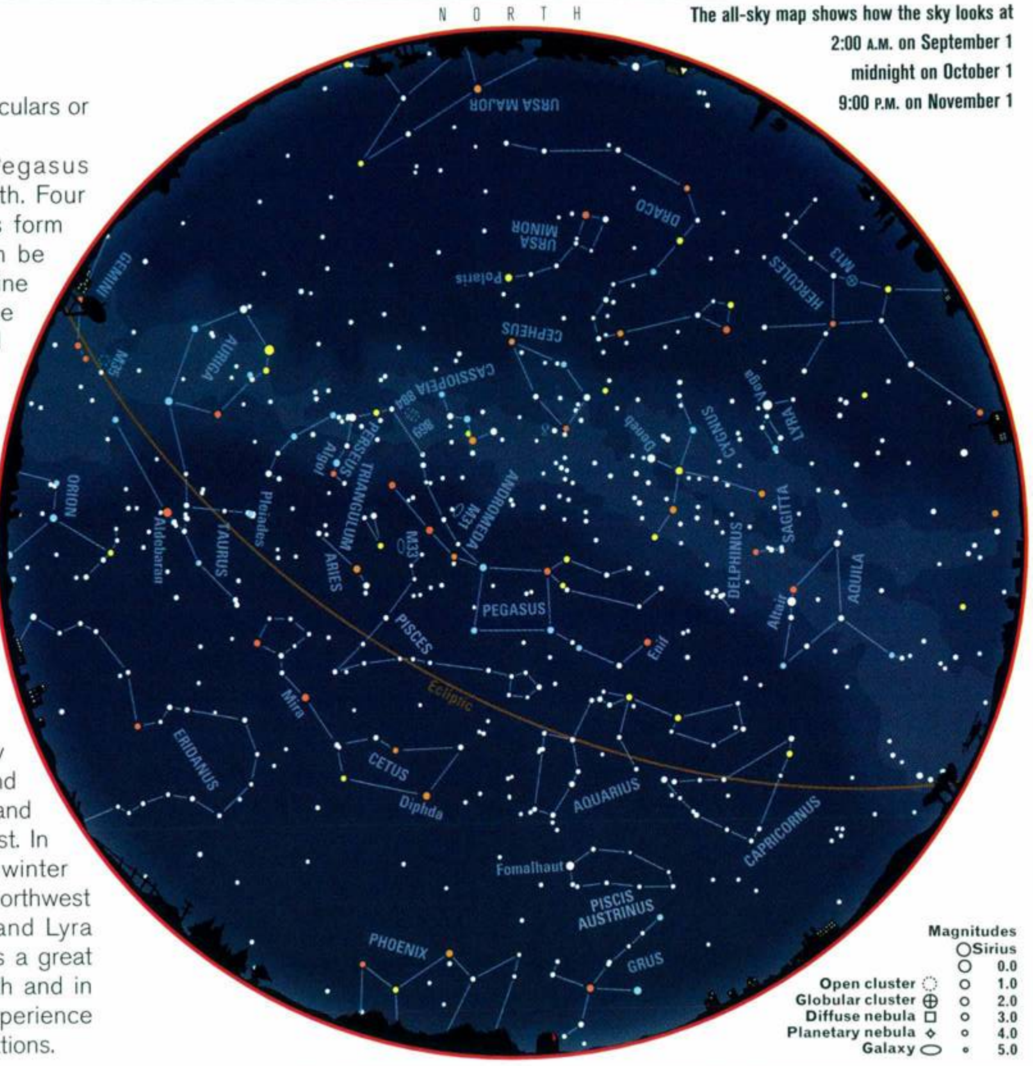
The cool nights of autumn are here to remind us that the chill of winter is not far off. Along with the cool air, the brilliant stars of the summer triangle descend in the west to be replaced with a rather bland looking region of sky. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to summertime, plus a couple of planets roam the region this year too.

The Big Dipper swings low this season, and for parts of the southern United States it actually sets. Cassiopeia, a group of five bright stars in the form of a "W" or "M," reaches its culmination overhead, the same point the Dipper reached six months ago. To the east of Cassiopeia, Perseus rises high. Nestled between these two groups is the wonderful Double Cluster – NGCs 869 and 884 – a fantastic sight in binoculars or a low-power telescope.

Our view to the south of the Milky Way is a window out of the disk of our galaxy in the opposite direction to that visible in spring. This allows us to look at the Local Group of galaxies. Due south of Cassiopeia is the Andromeda Galaxy (M31), a 4th-magnitude smudge of light that passes directly overhead between 9 P.M. and 10 P.M. in November. Farther south between Andromeda and Triangulum lies M33, a large, sprawling, face-on spiral best seen in binoculars or a rich-field scope.

The Great Square of Pegasus passes just south of the zenith. Four 2nd- and 3rd-magnitude stars form the square, but few stars can be seen inside of it. If you draw a line between the two stars on the right side of the square and extend it southward, you'll find 1st-magnitude Fomalhaut in Piscis Austrinus. Fomalhaut is the solitary bright star low in the south. Using the eastern side of the square as a pointer to the south brings you to Diphda in the large, faint constellation Cetus.

To the east of the Square lies the Pleiades Cluster (M45), which reminds us of the forthcoming winter. By late evening in October and early evening in December, Taurus and Orion are clear of the horizon and Gemini is rising in the northeast. In concert with the reappearing winter constellations, the view to the northwest finds summertime's Cygnus and Lyra about to set. The fall season is a great transition period, both on Earth and in the sky, and a fine time to experience the subtleties of these constellations.


The all-sky map shows how the sky looks at
2:00 A.M. on September 1
midnight on October 1
9:00 P.M. on November 1

N O R T H
URSA MAJOR
URSA MINOR
Polaris
DRACO
HERCULES
M13
LYRA
Vega
CYGNUS
Deneb
CEPHEUS
CASSIOPEIA
869
884
PERSEUS
Algol
TRIANGULUM
ANDROMEDA
M31
M33
PEGASUS
SAGITTA
DELPHINUS
Altair
AQUILA
Enif
ARIES
PISCES
Ecliptic
Pleiades
TAURUS
Aldebaran
AURIGA
GEMINI
M35
ORION
Mira
CETUS
Diphda
ERIDANUS
AQUARIUS
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
GRUS
PHOENIX
Magnitudes
Sirius
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5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

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4	5	6	7	◐	9	10
11	12	13	14	○	16	17
18	19	20	21	◑	23	24
25	26	27	28	29	●	

EST

2 **4 A.M.**
Mercury passes 5° north of Spica (morning)
7 A.M.
Venus passes 4° north of Spica (morning)

3 **5 P.M.**
The moon passes 0.6° north of Saturn

4 **1 P.M.**
Mars passes 2° south of Neptune (evening)

6 **2 A.M.**
The moon passes 1.7° north of Jupiter

17 Leonid meteor shower peaks

20 **4 P.M.**
The moon passes 3° south of Neptune

21 **2 P.M.**
The moon passes 3° south of Mars
9 P.M.
The moon passes 4° south of Uranus

26 **5 A.M.**
Mars passes 0.8° south of Uranus (evening)

27 noon
Vesta is at opposition

30 **9 P.M.**
The moon passes 0.5° north of Saturn

DEC

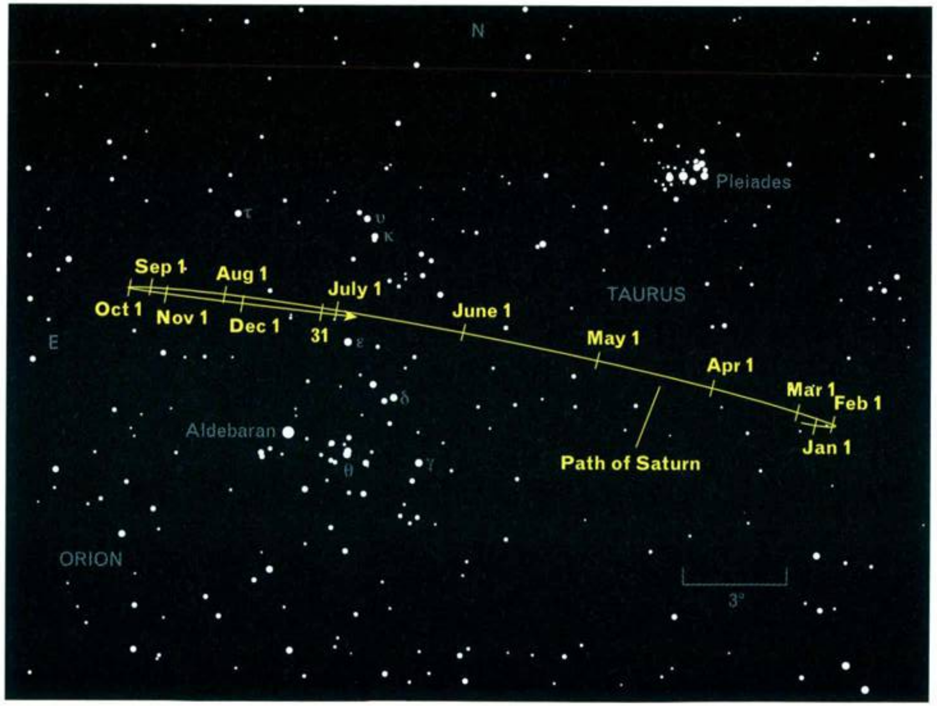
Saturn at Its Magnificent Best

Few things appear as breathtaking as Saturn through even a small telescope. Here's a world that's unlike any other in the solar system. Sure, Jupiter, Uranus, and Neptune all have ring systems of one sort or another, but none comes remotely close to the bright, glitzy rings of Saturn. This network of rings spans 170,000 miles from one end to the other but measures less than a mile thick. In comparison, Saturn itself has a diameter of about 75,000 miles, some nine times larger than Earth.

The best time to view Saturn this year comes in December, when the planet lies opposite the sun in our sky. At this configuration, known as opposition and occurring officially on December 3, the planet rises at sunset and appears highest in the sky around midnight. Not only will Saturn stay on view all night, but it appears brightest at opposition (magnitude –0.4) and largest in the eyepiece (21", with the rings spanning 47").

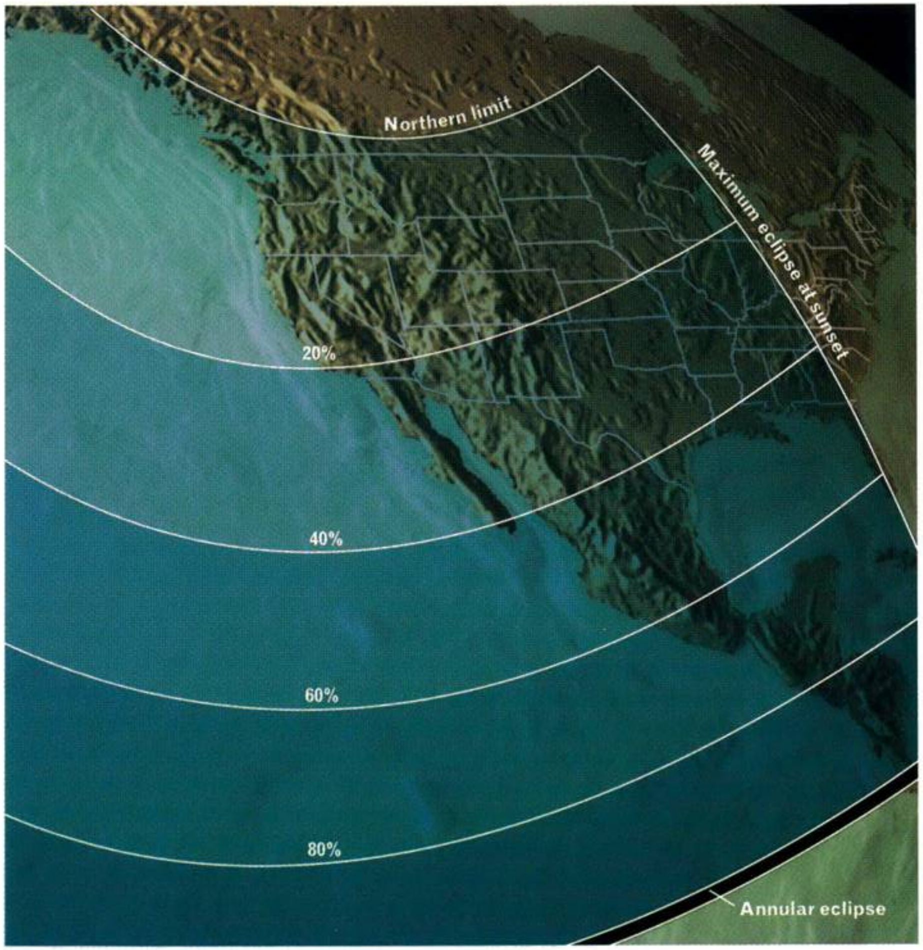
With the rings covering such a large apparent diameter and tilted wide open to our view, details can be seen quite easily. The outer A ring appears a little fainter than the inner B ring and the two are separated by a gap known as the Cassini division. All three of those features should be easy to see on a night of good seeing. If conditions seem particularly steady, try to make out the Encke division, a much finer dark gap that lies near the outer edge of the A ring, and the elusive, innermost Crepe ring.

Saturn is a stunning sight through any telescope, and its rings make the planet appear double in size. John Chumack



Even if all these rings come into view, don't think you're seeing everything Saturn's rings offer. Thanks to the Voyager missions to the outer planets, astronomers now know the rings are made up of countless thousands of tiny ringlets, some of which even occupy the supposed gap of the Cassini division. Planetary scientists will certainly learn even more about the planet and its environs once the Cassini spacecraft goes into orbit around the planet in 2004.

That mission will also drop a probe into the atmosphere of Saturn's largest moon, Titan. Titan, the second biggest moon in the solar system, shines brightly enough to be seen easily in any size telescope. A half dozen other moons will come into view with increasing aperture and increasing patience. But no matter how many times you view Titan, Tethys, Dione, Rhea, and the rest, you'll keep coming back to the rings — probably the most thrilling celestial sight in the entire solar system.



An annular eclipse graces Latin America while the partial phase can be observed in the United States. Barry Reynolds

The Sun's Second Disappearing Act

When people think of solar eclipses, they usually envision day turning to night and the appearance of the ghostly corona and fiery prominences leaping from the sun's limb. Spectacular? Of course. But the beauty of a solar eclipse shouldn't blind you to the immense joys of viewing other types of solar eclipses.

This year provides globe-trotting shadow chasers with a great opportunity to compare a total with an annular eclipse. The prospects for clear weather in southern Africa make the total eclipse of June 21 a must-go-to event for die-hard eclipse observers. On December 14, the moon's shadow once again touches Earth, treating residents of and visitors to southern Nicaragua and northern Costa Rica to an annular eclipse.

During an annular eclipse, the moon lies a little farther from Earth than during a total eclipse. That means the moon's disk appears slightly smaller in the sky — not quite big enough to block the sun's entire surface. Instead a bright ring, or annulus, of sunlight remains around the moon. In this month's eclipse, annularity lasts only a few seconds, so don't blink.

However, a good portion of North America will get to see a partial eclipse. The farther south and east you live, the more of the sun will be covered. From southern Florida, 60 percent of the sun will be hidden from view. That number drops to about 40 percent in the southeastern United States and to just 20 percent in the Great Lakes region. But for those who don't relish the thought of visiting southern Africa or Central America, it's hard to beat walking out your back door and being able to view a partial solar eclipse.

S	M	T	W	T	F	S
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2	3	4	5	6	◐	8
9	10	11	12	13	○	15
16	17	18	19	20	21	◑
23/●	24/31	25	26	27	28	29

EST

3 **6 A.M.** The moon passes 1.6° north of Jupiter
9 A.M. Saturn is at opposition

4 **5 P.M.** Mercury is in superior conjunction

6 **11 P.M.** Pluto is in conjunction with the sun

13 Geminid meteor shower peaks

14 **4 P.M.** Partial solar eclipse (visible in most of North America)

18 **2 A.M.** The moon passes 4° south of Neptune

19 **7 A.M.** The moon passes 4° south of Uranus

20 **3 P.M.** The moon passes 4° south of Mars

21 **2 P.M.** Solstice (northern winter/southern summer begins)

28 **3 A.M.** The moon passes 0.2° north of Saturn

30 **9 A.M.** The moon passes 1.2° north of Jupiter

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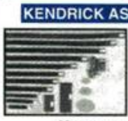

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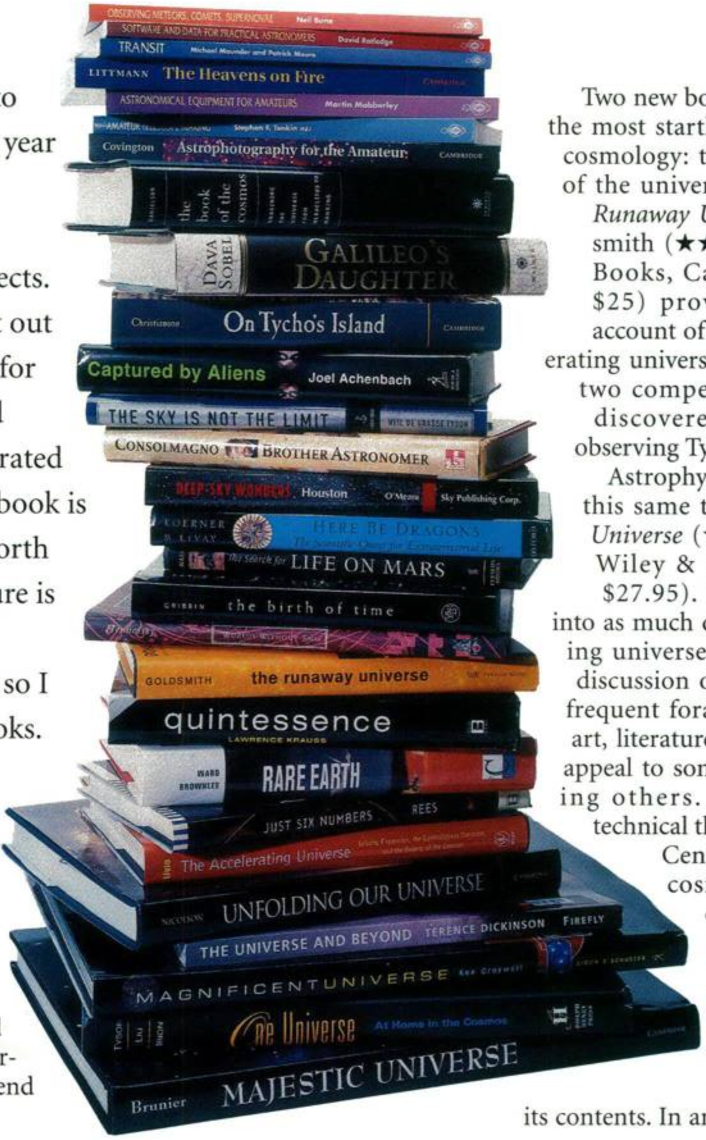
Astronomy's

BOOKS OF THE YEAR

Looking for something to read on a cloudy night?
This guide will help you separate
the wheat from the chaff.

by Robert Naeye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The Accelerating Universe
NICOLSON UNFOLDING OUR UNIVERSE
THE UNIVERSE AND BEYOND TERENCE DICKINSON FIREFLY
MAGNIFICENTUNIVERSE Ken Croswell
One Universe At Home in the Cosmos
Brunier MAJESTIC UNIVERSE

The period from mid-1999 to mid-2000 was another great year for astronomy books, with notable offerings on a wide variety of space-related subjects. This guide will help you sort out which books might be right for you, given your interests and level of expertise. Books are rated from ★ to ★★★★★. A good book is ★★★, a very good book is worth ★★★★, and a timeless treasure is worth ★★★★★. I've avoided books worth less than ★★★, so I recommend any of these books.

NEWCOMERS to astronomy will find it hard to beat *Astronomy for Dummies* (★★★★, 310 pages, IDG Books, Foster City, Calif., 1999, $19.99) by NASA astronomer Stephen P. Maran. This book provides a tutorial on all major aspects of astronomy, from mythology and observing to cosmology. The user-friendly text and illustrations extend a welcome mat to novices.

Two new books are devoted to one of the most startling recent discoveries in cosmology: the apparent acceleration of the universe's expansion rate. *The Runaway Universe* by Donald Goldsmith (★★★★, 232 pages, Perseus Books, Cambridge, Mass., 2000, $25) provides a straight-ahead account of cosmology and the accelerating universe. Goldsmith details how two competing astronomy groups discovered the acceleration by observing Type Ia supernovae.

Astrophysicist Mario Livio covers this same topic in *The Accelerating Universe* (★★★★, 274 pages, John Wiley & Sons, New York, 2000, $27.95). Livio's book doesn't go into as much detail about the accelerating universe; it is more of a general discussion of cosmology. Livio takes frequent forays into the aesthetics of art, literature, and science, which will appeal to some readers while distracting others. Livio's book is more technical than Goldsmith's.

Central to any discussion of cosmology is the nature of dark matter. This invisible stuff serves as a reminder to astronomers that they can't claim to understand the universe when they can't identify more than 90 percent of its contents. In an update of his 1989 book

The Fifth Essence, physicist Lawrence Krauss's *Quintessence* (★★★, 356 pages, Basic Books, New York, 2000, $26) summarizes the various possibilities for dark matter and how physicists and astronomers are trying to unravel its secrets by conducting exceedingly difficult and complex experiments. The book is semitechnical in spots.

In *Just Six Numbers* (★★★⯨, 173 pages, Basic Books, New York, 2000, $22), Britain's Astronomer Royal, Martin Rees, focuses on six physical parameters that shape the universe's characteristics and destiny. If they had slightly higher or lower values, Rees maintains, the universe would be sterile, and we wouldn't be around to ask the question of why we're so lucky these parameters have the values they do. Rees speculates that our universe is just one of many, and most of these other universes are lifeless.

Our fascination with extraterrestrial life guarantees this subject will continue to be fodder for popular science books. This past year was no exception. Leading the charge is the controversial *Rare Earth* (★★★★, 333 pages, Copernicus Books/Springer, New York, 2000, $27.50), by paleontologist Peter Ward and astronomer Donald Brownlee. The two University of Washington scientists raise a litany of arguments to support their contention that the universe is brimming with simple life but that complex life — and by extension, intelligent life — is extremely rare.

In another astronomer/biologist collaboration, David Koerner and Simon LeVay take a more agnostic approach to the question of ET life in *Here Be Dragons* (★★★⯨, 264 pages, Oxford University Press, New York, 2000, $27.50). While less provocative than *Rare Earth*, *Here Be Dragons* will appeal to those who want a comprehensive treatment of the issues without a biased viewpoint.

While not a "hard" science book like those mentioned above, *Captured by Aliens* (★★★★★, 415 pages, Simon & Schuster, New York, 1999, $25) by *Washington Post* writer Joel Achenbach offers insightful commentary on attempts by scientists and even UFO fanatics to find ET life. Don't be deceived by the title — the book takes the subject matter seriously. For sheer reading pleasure, this book is worth a sixth star. Achenbach fills the pages with hilarious one-liners such as this description of NASA administrator

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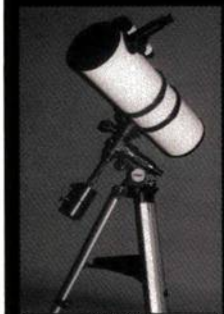

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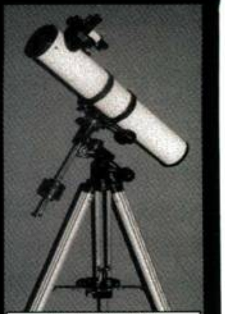

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Dan Goldin: "After a while with Goldin, you simply get used to the fact he sounds like Captain Kirk, minus the clenched fist and pajama top."

THE PAST YEAR has been a good one for the coffee table genre, with several notable offerings. The third edition of Terence Dickinson's *The Universe and Beyond* (★★★★★, 168 pages, Firefly Books, Kingston, Ontario, 1999, $29.95) offers an unbeatable combination of spectacular images, beautiful space art, and lively prose. Chock-full of new photos, along with recent information about extrasolar planets, black holes, and other topics, this timeless treasure is worth your money even if you own an earlier edition.

Magnificent Universe (★★★★, 210 pages, Simon & Schuster, New York, 1999, $60) by Ken Croswell serves up a whirlwind tour of the universe, starting with the solar system and ending with a thorough discussion of cosmology. Croswell delivers eloquent and insightful analysis while splashy images spread over a large-page format reveal the breathtaking glory of the universe.

While not as visually spectacular as the previous two entries, *One Universe* (★★★★, 218 pages, Joseph Henry Press, Washington, D.C., 1999, $40) by astrophysicists Neil de Grasse Tyson and Charles Liu and *Astronomy* contributing editor Robert Irion distinguishes itself from the competition with its highly effective and original organization. Eschewing the conventional solar system-to-cosmology organization of most coffee table books, the authors center their narrative around three basic physical concepts: motion, matter, and energy. Like the previous two books, this work deserves to be read as well as seen.

In the autobiography *The Sky Is Not the Limit* (★★★, 191 pages, Doubleday, New York, 2000, $23.95), *One Universe* coauthor Neil de Grasse Tyson, director of New York's Hayden Planetarium, describes the social obstacles placed in front of an African-American desiring to pursue a career in astronomy. Tyson's relaxed writing style makes the book a pleasurable read, but don't expect in-depth information about Tyson's scientific research or his work in renovating the Hayden.

Guy Consolmagno of the Vatican Observatory describes astronomical research under the Catholic Church in *Brother Astronomer* (★★★⯨, 229 pages, McGraw-Hill, New York, 2000, $24.95). Consolmagno explains how he reconciles scientific thought with religious faith and debunks the notion that the Church is hostile to science.

For historical works, Dava Sobel followed up her surprise 1995 bestseller *Longitude* with *Galileo's Daughter* (★★★, 420 pages, Walker & Company, New York, 1999, $27). The book is based on Galileo's letters to his illegitimate daughter Virginia, who later adopted the name Suor Marie Celeste when she joined a convent. Through the letters, we gain a fresh perspective on Galileo's life and times.

History buffs might also be intrigued by John Robert Christianson's *On Tycho's Island* (★★★⯨, 452 pages, Cambridge University Press, New York, 2000, $34.95). This book tells the story of the intellectual center Uraniborg on the Baltic island of Hven. Danish astronomer Tycho Brahe, who was arguably the greatest observer of the pretelescopic era, was the director.

In the realm of amateur astronomy, *Deep-Sky Wonders* (★★★★★, 309 pages, Sky Publishing, Cambridge, Mass., 1999, $29.95) is a beautifully written compilation of *Sky & Telescope* articles by the late Walter Scott Houston, a legendary deep-sky observer.

Comet aficionados should check out Robert Burnham's *Great Comets* (★★★★, 224 pages, Cambridge University Press, New York, 2000, $21.95). Burnham, a former editor of *Astronomy*, not only explains what makes a great comet great, he puts them in their scientific and historical context.

For both budding and intermediate astrophotographers, I highly recommend *Astrophotography for the Amateur, second edition* (★★★★, 331 pages, Cambridge University Press, New York, 1999, $34.95) by Michael A. Covington. This updated edition includes new information about choosing telescopes, films, and cameras, along with advice on how to take and process images with CCDs.

If one of your favorite books didn't make this list, it's because this article didn't have enough space to cover all the fine astronomy books published in the last year. But I hope you've spotted a few titles that have sparked an interest for those cloudy nights when you can't observe.

Robert Naeye is senior editor and book review editor for Astronomy.

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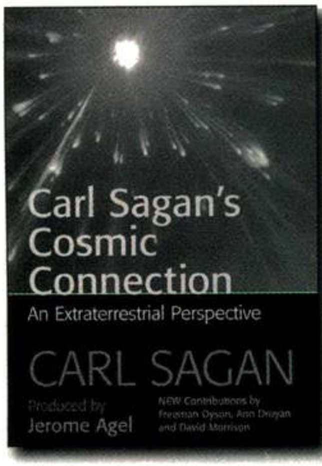
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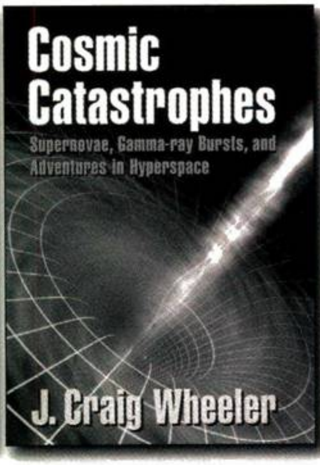
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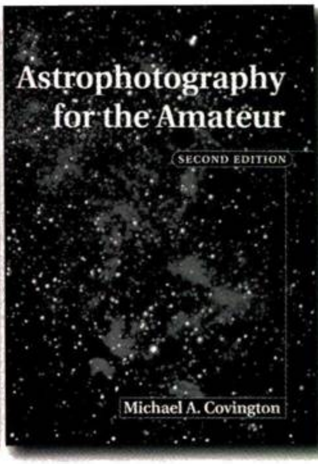
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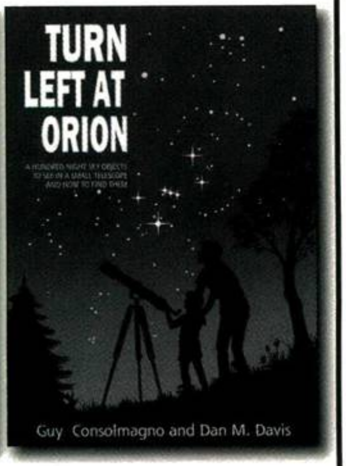
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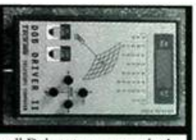

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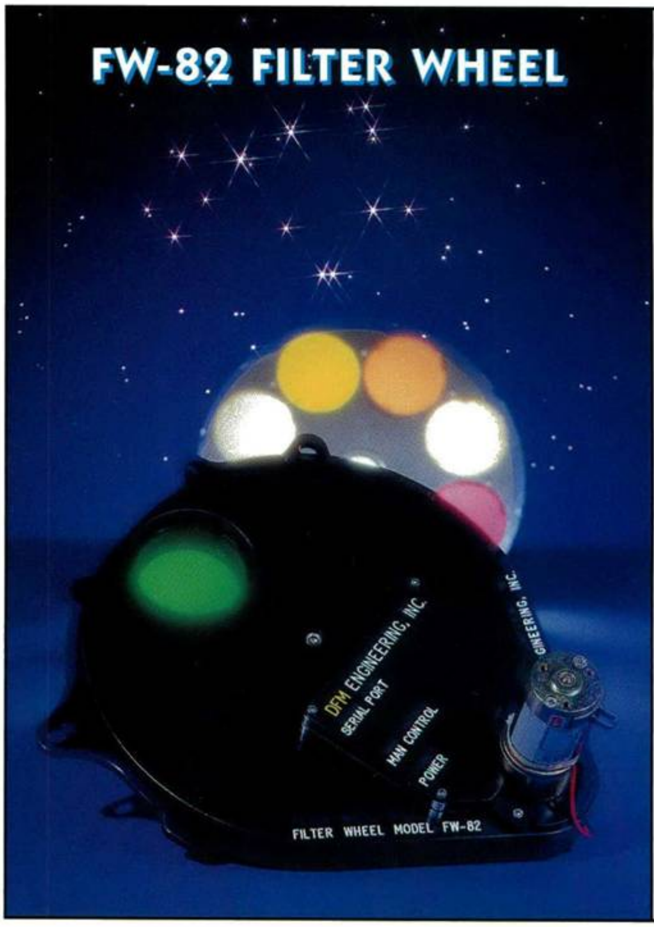

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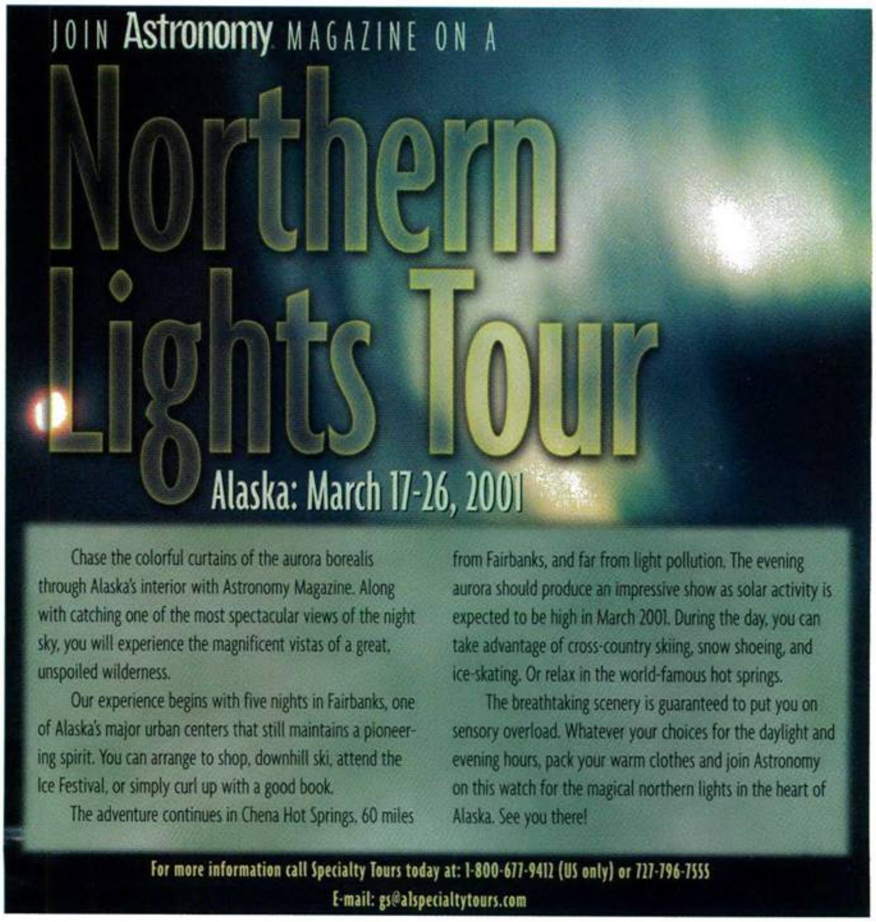

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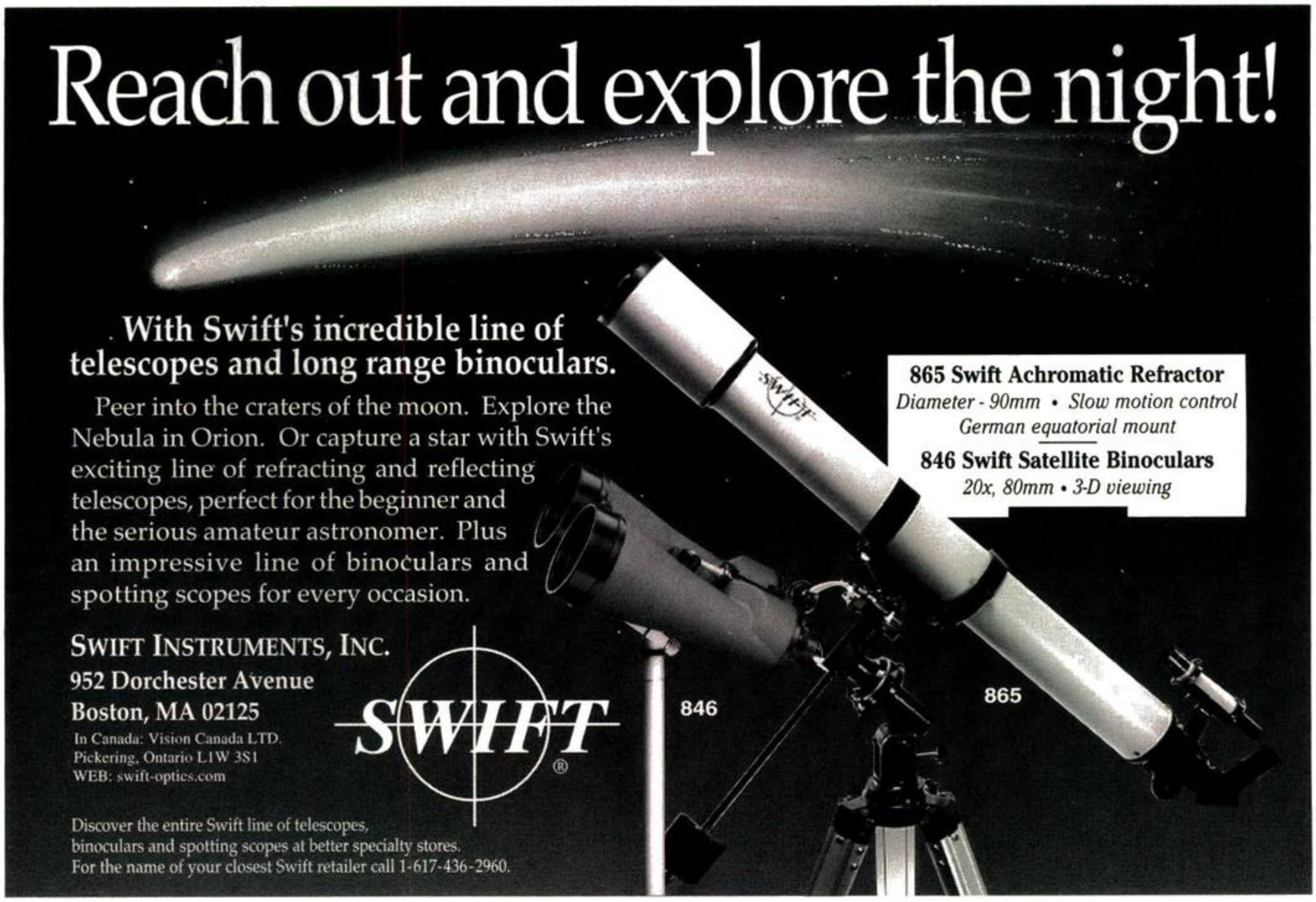

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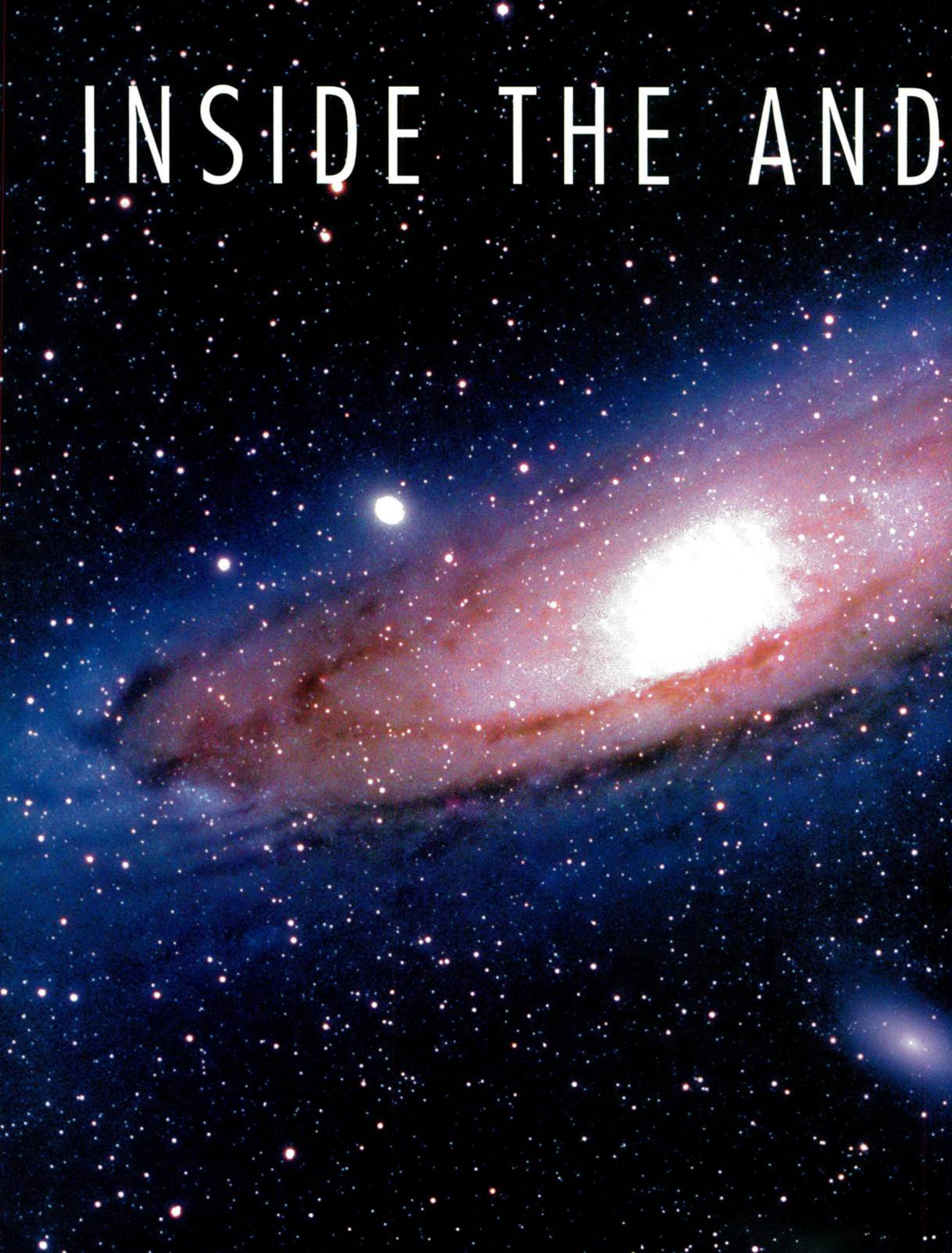
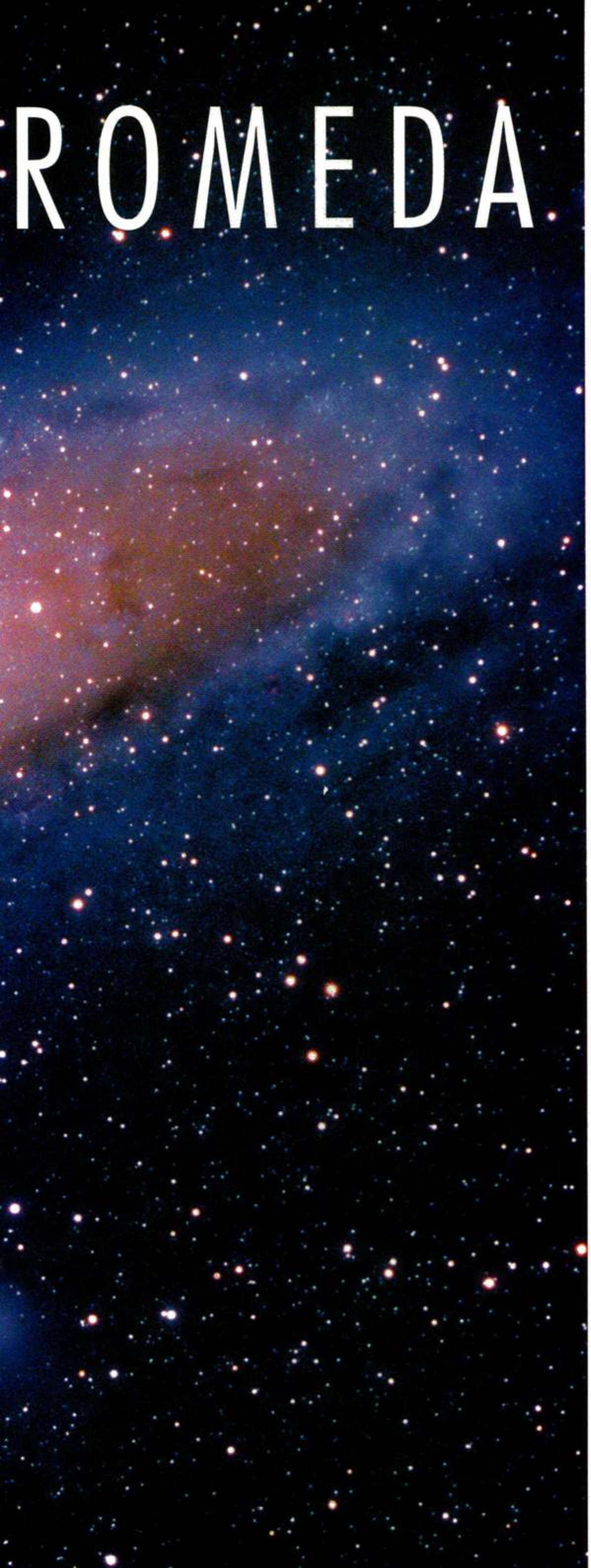


ROMEDA GALAXY

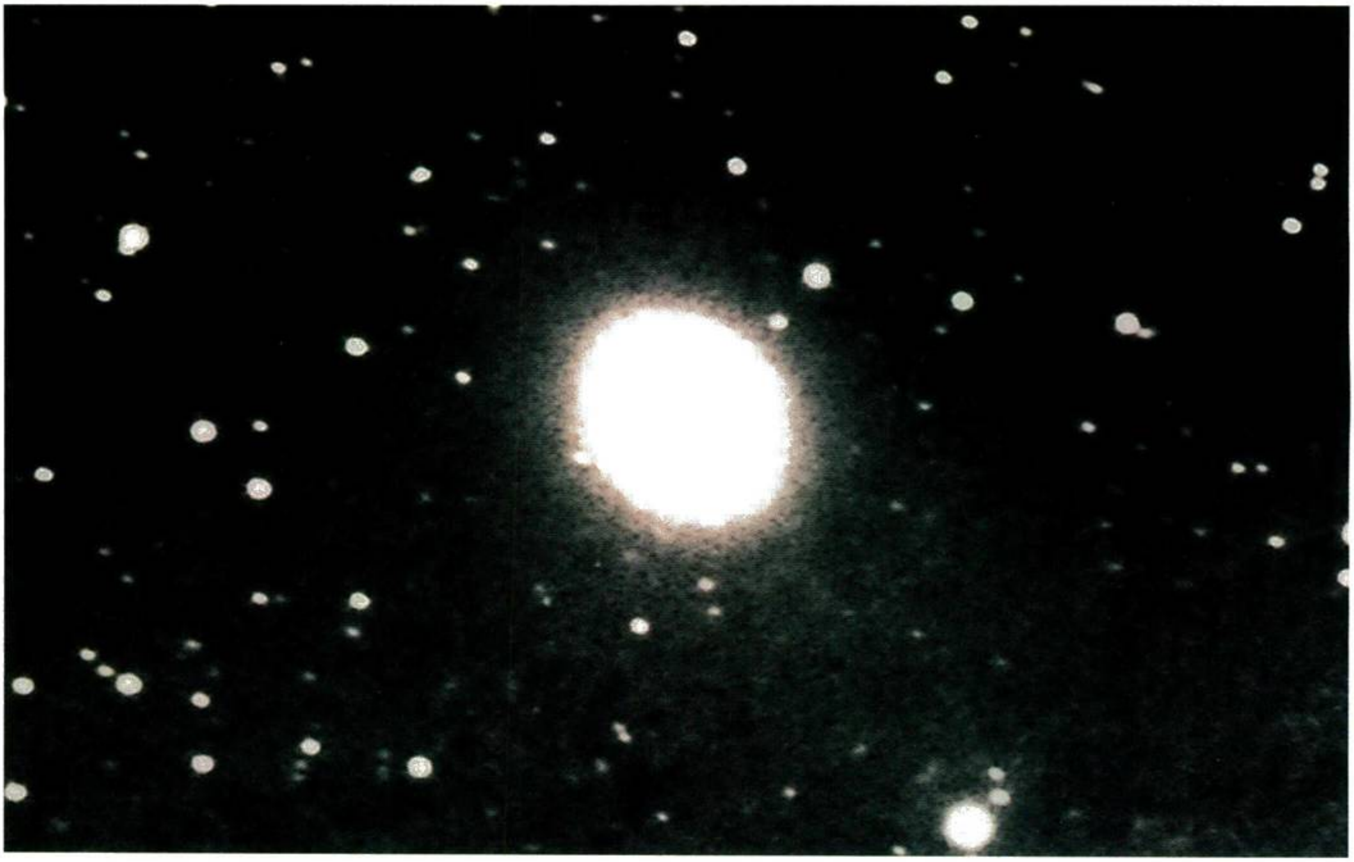


Check out M31, guaranteed to please in both big scopes and small.

by Alan Goldstein

The most celebrated galaxy in the sky, M31, the Andromeda Galaxy, routinely graces the photo galleries of astronomy magazines and the covers of books. The galaxy certainly is the most studied outside our own, as it is the sister spiral to the Milky Way in the Local Group, our loose-knit neighborhood of galaxies. It is also the largest and brightest galaxy in the sky, setting aside the irregular Magellanic Clouds, which lie deep in the Southern Hemisphere (and which are satellites of our own system). It's no wonder that the Andromeda Galaxy has garnered one of the top spots on observers' checklists, as it is the most distant object easily visible to the naked eye and offers an array of details to patient observers with moderate-sized telescopes.

The brightest spiral in the sky, M31, offers rich details to users of backyard scopes. Jerry Lodriguss



The brightest of the Andromeda satellites, M32, lies tucked near one of the big galaxy's dusty spiral arms. Gary Jones and Mike Warnell

To the eye alone, M31 appears as a misty spot 13° northeast of Alpheratz (Alpha Andromedae), the constellation's brightest star. Star-hoppers find it by aiming their finderscopes at Mirach (Beta And), moving northwestward past Mu And, and on to two bright stars, Nu and 32 And, which form a right triangle with the Andromeda Galaxy's nucleus. If you spot the misty glow with your eye from a dark site, stretch out your arm and hold up one finger. A finger's width represents about 2°, or the span of four moons side by side. The Andromeda Galaxy spreads over 3°, and sharp-eyed observers in the darkest locations have claimed to see the disk extending 4°.

Binoculars reveal hints of detail in the galaxy. Look carefully to see where the luminous disk fades into the blackness of the surrounding sky, noting which stars border the galaxy (you might make a drawing based on several minutes of watching). How far out does the disk extend? Comparing the sketches to photographs of the galaxy will show exactly how much of the disk you can see. You may catch a glimpse of the two bright satellites, M32 and NGC 205, with binoculars. M32 is small enough that it might be mistaken for a star at low power. NGC 205 is much larger but has a lower surface brightness, meaning its light is spread out enough that it may require dark skies or be washed out by light pollution.

SIZING UP ANDROMEDA

The Andromeda Galaxy is a spectacular object in amateur telescopes because it's large, bright, and relatively close. The Local Group floats on an outer edge of the so-called Virgo Supercluster of galaxies, a giant group of hundreds of galaxies whose center lies about 70 million light-years off. More than 30 galaxies are Local Group members, floating in a bubble of space spanning 5 million light-years. The Andromeda Galaxy is the big boy on the block, its bright disk component measuring 130,000 light-years across; the Milky Way's disk is some 75,000 light-years across. While the Milky Way has the two Magellanic clouds and nine tiny dwarfs as satellites, Andromeda has at least 12 dwarf spheroidal or irregular companions that orbit its center. The main companions, which appear very close to M31's disk, are the relatively bright M32 and NGC 205 (sometimes designated M110). Farther away lie two dimmer elliptical companions, NGC 147 and NGC 185 (visible in Cassiopeia from our vantage point). The other companions are very faint but can be imaged with long-exposure photography or CCD imaging; they are extremely challenging to visual observers armed with only a telescope.

The distance to the Andromeda Galaxy is not precisely agreed upon, the answer varying a bit depending on the methods astronomers use to find it. Measuring the brightnesses of Cepheid variable stars within the galaxy yields a distance of 2.5 million light-years. Measuring the brightnesses and behavior of RR Lyrae variables and so-called

NGC 205, sometimes designated M110, appears as a glowing haze encapsulated in dust. Kim Zussman

Cassiopeia's NGC 185 (left), not far from NGC 147, is another dusty and elusive satellite of M31's. R. Pecce

Stubbornly difficult IC 10 (above) in Cassiopeia poses the greatest challenge for observing M31's satellite galaxies. Martin C. Germano

red tip branch stars gives a slightly smaller distance. Measuring the magnitudes of bright stars within some of the globular clusters in M31 provides a distance of 2.7 million light-years.

The dynamics of Andromeda tell us a little about what will happen inside the Local Group. Although most galaxies are moving away from each other in space, Andromeda is approaching the Milky Way at a rate of 190 miles per second. It's coming at us faster than any other galaxy in the sky. A collision probably won't happen until a few billion years from now, however, at least according to astronomer Halton C. Arp, who says the galaxies will pass "like ships in the night." Gravitational interaction from Andromeda's vast halo of dust could alter the Milky Way's spiral arms, and M31 could appear as large as the Large Magellanic Cloud in our sky for a few eons.

DISSECTING THE GREAT GALAXY

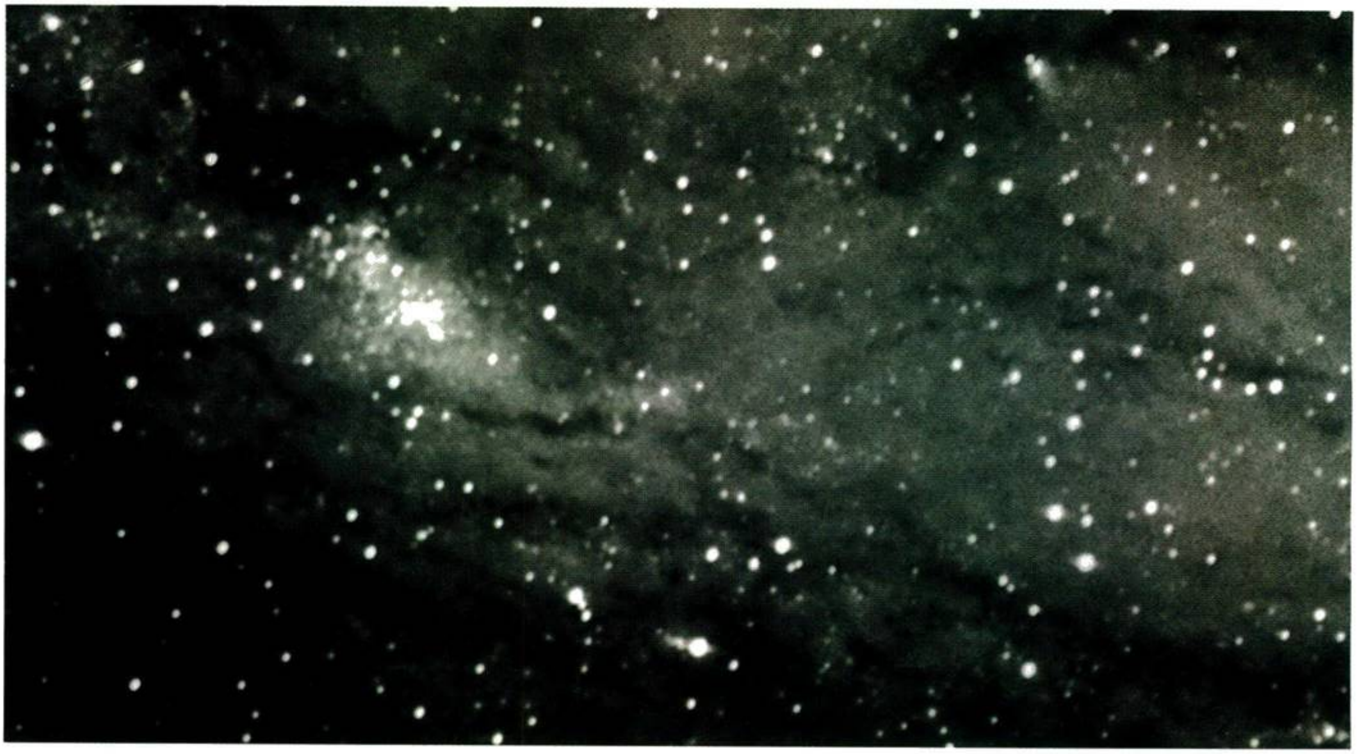
Andromeda is a superb example of a spiral galaxy, and its tilt of 77.5° to our line of sight lets us see a broad range of spectacular features in photos and at the eyepiece. Spiral galaxies have a core, or nucleus; a central hub; and a disk which may or may not contain distinct spiral arms littered with gaseous nebulae, star clusters, stellar associations, clouds of dust, veins of dark nebulae, and superluminous stars. The outer haloes of spiral galaxies contain vast shells of ionized hydrogen gas, dust, ancient stars, and an array of globular clusters. The variety of shapes and sizes of spirals allows astronomers to classify their structures. Andromeda is an Sb-type galaxy in the Hubble classification system, devised by Edwin Hubble decades ago. This means it has a moderate-sized central hub and disk. More recently, astronomer Gerard de Vaucouleurs classified M31 as an SA(s)b galaxy, meaning it is a regular spiral with S-shaped spiral arms and a moderate-sized central hub and disk.

Elusive M31 satellite NGC 147, located in Cassiopeia, offers an observing challenge. Harvey Freed

Andromeda has some special features that may or may not be common among such spirals. Hidden deep within the galaxy's center is a double nucleus discovered several years ago that holds a supermassive central black hole within a huge cluster of hot B- and A-type stars. The black hole has drawn in a mass equivalent to more than 300 million suns. Curiously, the Milky Way has a similar structure in its center, a smaller black hole of its own, and is more active in radio wavelengths than M31's nucleus.

In a telescope, Andromeda's nucleus appears as a fuzzy, starlike object — resolving it into the two components is out of the question. It may appear as an elongated blob glowing softly at magnitude 12.6. At the galaxy's distance, the scale is 1' = 600 light-years, so you can perceive objects as small as a few dozen light-years at a time. Calculating the field diameter of your eyepiece allows estimating how many light-years' worth of the galaxy you are seeing in one view — a curious exercise. On nights of superb seeing, some observers claim to see a slightly orangy color in the nuclear light.

The Andromeda Galaxy's inner hub consists of the highest concentration of stars in our Local Group. It's visible in a telescope even under light-polluted skies. The inner hub holds hundreds of thousands of old, so-called Population II stars, giving the hub a yellowish tinge. The sheer number of stars in the hub makes resolving structure difficult, even for the Hubble Space Telescope. Dark nebulae cut and twist across the hub, blocking communities of stars beyond. The galaxy's spiral arms wrap around its central hub. Because the arms are tilted 77.5° to our line of sight, they are greatly foreshortened and indistinct. Some 50 years ago the American astronomer Walter Baade proposed that the galaxy might contain two arms wound over three or four revolutions. A larger number of fragmented arms may actually exist,



M31 is so close that sharp-eyed observers can pick out a mammoth star cloud, NGC 206, in its midst.

Paul Roques

however. Recent studies by Michael Haas of NASA's Ames Research Center have revealed a ring of cold dust around the galaxy's hub, extending out 30,000 light-years. This inner dust, made of extremely fine carbon particles, may be engineering a ringlike structure that will develop in M31's inner arms at some future time.

While the spiral structure and dust lanes are not terribly conspicuous, they can be traced in a 6-inch telescope on a dark, moonless night. Stellar associations, groups of young O and B stars, inhabit the spiral arms and act as tracers. Unlike open and globular clusters, associations are linked gravitationally only loosely and so dissipate over fairly short timescales. Sidney van den Bergh of the Dominion Astrophysical Observatory studied M31's associations in the 1960s and helped to catalog the 188 now known in the galaxy, varying in size from 300 to more than 7,000 light-years across. Dust lanes and pockets cross the arms and intermingle with the associations; looking carefully at a photo of the galaxy shows that the close edge, with its detailed dust band, is the northwestern side, opposite the nucleus from M32. Paul Hodge of the University of Washington has exhaustively cataloged more than 700 dark nebulae within the galaxy.

Under pitch-black skies, a handful of associations is visible to users of 10- or 12-inch telescopes. The most prominent group of stars in M31 is not really an association but a detached "star cloud," NGC 206, a wall of bright stars whose edges are delineated by dark nebulae. Located in the galaxy's southwestern quadrant, some 40' from the galaxy's center, NGC 206 is visible with even a 6-inch scope on a dark night. Once you're in the area, boost the magnification to moderate power to help isolate the star cloud.

Open star clusters and emission nebulae — the stellar birthplaces that produce open clusters — are scattered all throughout M31 but are too faint to detect in all but the largest amateur telescopes. Some 400 open clusters are known to exist; more than 1,000 emission nebulae float among the galaxy's arms, most overpowered by the light of the brilliant star

ANDROMEDA GALAXY FACTOIDS

Andromeda Galaxy (M31, NGC 224)
R.A. 0h42.7m, Dec. 41°16′
Type: SA(s)b
Distance: 2.5 million light-years
Diameter: 130,000 light-years
Visual magnitude: 3.5
Dimensions: 177.8′ by 63.1′
Inclination to our line of sight: 77.5°

M32 (NGC 221)
R.A. 0h42.7m, Dec. 40°52′
Type: cE2
Distance: 2.5 million light-years
Diameter: 2,000 light-years
Distance from M31: 16,300 light-years
Visual magnitude: 8.2
Dimensions: 7.6′ by 5.8′

NGC 205 (sometimes called M110)
R.A. 0h40.3m, Dec. 41°41′
Type: E5 pec
Distance: 2.5 million light-years
Diameter: 5,000 light-years
Distance from M31: 23,000 light-years
Visual magnitude: 8.0
Dimensions: 17.4′ by 9.8′

Aside from the wide swath of dust running along our own Milky Way, the Andromeda Galaxy offers observers the best look at a galaxy's band of obscuring dust.

Martin C. Germano

cluster they contain. The galaxy also holds many luminous stars, but they are generally far too faint to be seen in backyard scopes. The galaxy's brightest stars are blue luminous variables like Eta Carinae in our galaxy; the brightest of these, AF Andromedae, fluctuates between magnitudes 15.5 and 16.5. The brightest star ever observed in the Andromeda Galaxy was S Andromedae, a supernova that reached magnitude 5.9 in August 1885. It was the brightest extragalactic supernova known until the explosion of Supernova 1987A in the Large Magellanic Cloud some 14 years ago.

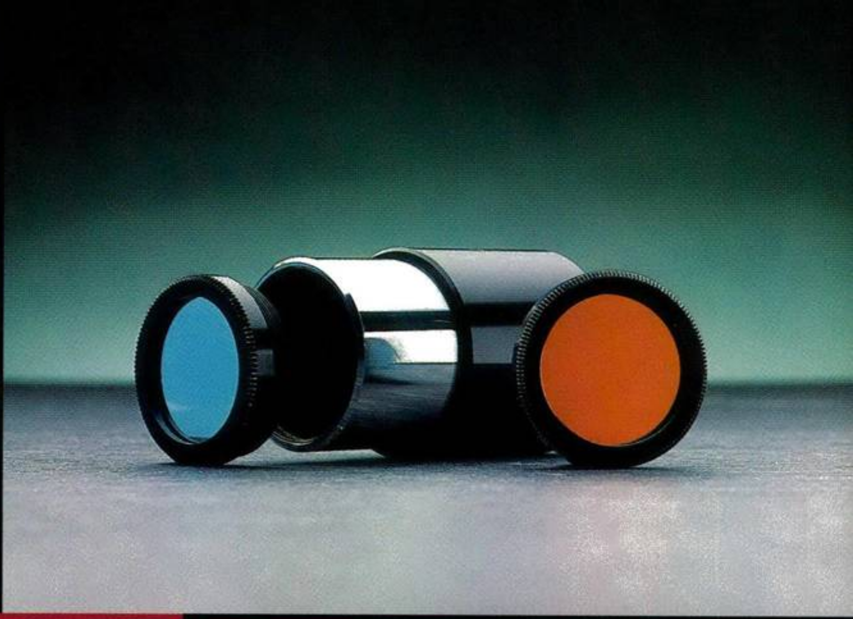
INTO ANDROMEDA'S HALO

Astronomers have busily cataloged more than 200 globular clusters floating in the galaxy's halo, a considerable collection when compared to the 140 known in the Milky Way. Andromeda's globular clusters are similar to the Milky Way's but richer in metals. Most of these lie within 60,000 light-years of M31's nucleus and a number of them are brighter than magnitude 15.5, making them visible in amateur scopes. Two of M31's globulars are standouts. G-1 (Mayall II) is one of the most distant (130,000 light-years away from the galaxy's center) and is the largest and brightest, glowing at magnitude 13.7. If it were placed beside Omega Centauri, the best globular in the Milky Way, G-1 would put its neighbor to shame in terms of size and brightness. G-185 appears to be a dual globular cluster, with a primary and a companion cluster separated by 50 light-years. Whether or not the two clusters are orbiting each other or simply form a line-of-sight alignment needs to be definitively solved by a variety of future measurements.

The two innermost satellite galaxies, M32 and NGC 205, are a joy to observe. M32 is a compact elliptical practically in contact with the Andromeda Galaxy. It's responsible for some of the larger galaxy's distortion in the spiral arm pattern. Considering its small size, M32 is remarkably dense: the nucleus of M32 is unusual for its size by virtue of holding a black hole with an estimated mass of 30 million suns. The elliptical NGC 205 is unusual in several respects. It has a clumpy, dusty center with at least 10 brilliant O and B stars in the nucleus, the result of a relatively recent inner burst of star formation. Unlike M32, the inner region of NGC 205 is not packed tightly with stars. The two brightest of the remaining satellites, NGC 147 and NGC 185 in Cassiopeia, are far more of a challenge to observe, requiring dark skies and a moderate-sized scope.

The Andromeda Galaxy should be a regular stop on your hit list of greatest astro targets. Not only is it the brightest spiral galaxy in the sky, but its retinue of details — clusters, associations, dark lanes, and satellites — gives you a unique opportunity to see details not visible in the vast majority of galaxies scattered across the sky. Unlimber your scope this summer and autumn and explore its reaches — you'll be studying the Milky Way's partner that ultimately will come flying in toward us in a vast cosmic dance. A

Alan Goldstein, cofounder of the National Deep-Sky Observers Society, has contributed many articles to Astronomy *and* Deep Sky *magazines. He wishes to thank Paul Hodge, Sidney van den Bergh, and John Kielkopf for assistance.*



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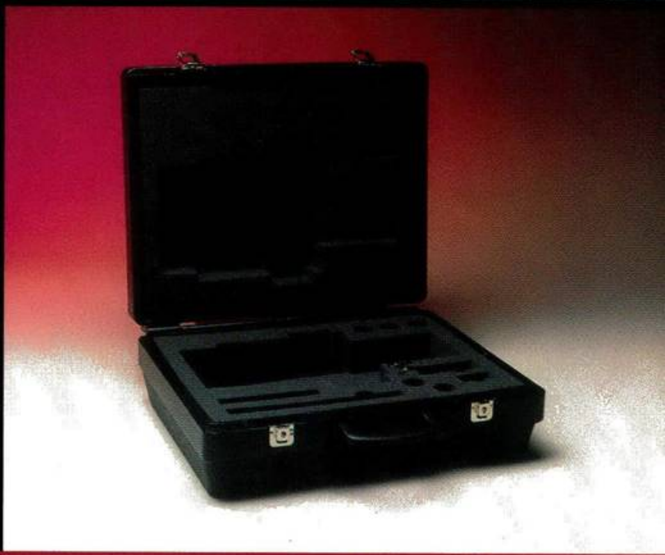

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2001 Buyer's Guide to Accessories

Some simple guidelines will help you navigate the bewildering array of astronomical accessories.

by Phil Harrington

Amateur astronomers have never had it so good. We may select from mammoth reflectors, exquisitely constructed refractors, and versatile, compact catadioptric telescopes. But just as amazing is the assortment of accessories for those telescopes. Besides finderscopes of all shapes and sizes, there are eyepieces, filters, collimators, dew eliminators, cases, and so much more.

But all that variety can lead to confusion. "Which brand should I choose?" and "Is that *really* necessary?" are two questions that every amateur astronomer asks at one time or another. This guide to astronomical accessories may clear up a little of the mystery.

Eyepieces

Nothing breathes new life into a telescope like a high-quality eyepiece. With the possible exception of selecting the telescope itself, picking the proper eyepiece or eyepieces is probably the most difficult choice facing today's amateur astronomers. Most amateur astronomers assemble a collection of eyepieces, so they can view objects over a range of magnifications.

Many telescopes come supplied with Kellner eyepieces, though some manufacturers refer to them as Modified Achromats (abbreviated MA) or Super Modified Achromats (SMA). Call them what you will, Kellner eyepieces are fine to start with, but you can do much better. For one, Kellner eyepieces have a restricted apparent field of view. Most observers find larger fields to be more aesthetically pleasing. Perhaps the greatest drawback of the Kellner design is its propensity for internal reflections, which are especially noticeable on bright objects. But thanks to antireflection optical coatings, this effect is mostly eliminated when used with 8-inch and smaller telescopes.

The table accompanying this article lists most of the best eyepieces currently available. Details are broken down first by design and then alphabetically by manufacturer. Some may be purchased from a number of different retailers, while others are available from only the listed source. Each entry also includes the eyepiece's focal length, barrel diameter, apparent field of view, eye relief, and typical retail price (prices may vary from dealer to dealer, and may change over time).

When choosing an eyepiece, always consider its magnification in your particular telescope. To calculate the magnification, simply divide your telescope's focal length by the eyepiece's focal length. Use only as much magnification as you need to see your target. If you own a smaller telescope (that is, 8 inches or less in aperture), don't exceed 60x per inch of aperture. Even with larger instruments, it's usually best not to exceed 300x unless seeing conditions are absolutely ideal — which is a very rare occurrence.

While an eyepiece's physical size depends on its internal design, the barrel (the part that slips into the telescope's focusing mount) is always one of three diameters. Most amateur telescopes use 1.25-inch diameter eyepieces, a standard that has been around for years. At the same time, many inexpensive, department-store telescopes are outfitted with 0.965-inch eyepieces (sometimes called *sub-diameter* eyepieces). But there has also been a recent boom in a whole new breed of 2-inch barrel eyepieces.

Not long ago, only monster telescopes selling for thousands of dollars could accept 2-inch eyepieces. Recently, however, a few manufacturers have added them to their smallest, least expensive scopes. But beware, this is mostly a marketing gimmick. Unless your telescope has an aperture 8 inches or larger, stick with 1.25-inchers. And should your telescope accept only 0.965-inch eyepieces, consider purchasing a 1.25-inch adapter (discussed later in this article). Although the 0.965-inch eyepieces included in the tables are far better than those that come with most telescopes, you will still need to convert to 1.25-inch eyepieces if you upgrade to a larger instrument. Remember, the eyepieces that you buy today can be used in any telescope you purchase in the future.

Besides magnification, pay close attention to *eye relief*, the distance the observer's eye must be from the eyepiece to view the entire field. Notice how eye relief usually shrinks with focal length. Some inexpensive eyepieces only have eye relief values one-quarter their focal length, which requires you to get much too close to the glass for comfortable viewing. Choose an eyepiece with an eye relief of at least 10mm, and if you must wear glasses, closer to 20mm.

In general, Plössl eyepieces are probably the best all-around eyepiece design for the money. They offer a reasonably wide apparent field of view, good color correction, and sharp images. Those primarily interested in observing the planets might do better with either orthoscopic or Brandon eyepieces, both of which are known for very sharp, contrast-rich images.

Finally, hybrid eyepieces, such as Lanthanums, Ultimas, Ultrascopics, and others, reflect the latest in optical design. Most use between six and eight optical elements (lenses) to create extremely wide fields of view that give you the feeling that you're peering through the porthole of an interstellar spaceship. But that "ticket" is a costly one, because most hybrids carry hefty price tags. While wonderful in larger instruments, you should not feel as though you are missing the fun if you do not own one.

Barlow Lenses

If you're looking for a quick and cheap way to double the number of eyepieces in your collection, then buy a Barlow lens. A Barlow lens, in its simplest form, is a "negative" (double convex) lens that, when inserted between a telescope's objective or mirror and the eyepiece, stretches the instrument's focal length by a factor usually between two and three times. For any given eyepiece, inserting a Barlow lens will thus double or triple the magnification. When shopping for a Barlow lens, make sure that it has fully coated optics. Fully multicoated optics are even better.

Eyepiece Adapters

If your telescope's focuser accepts only 0.965-inch eyepieces, but you want to use standard 1.25-inch eyepieces, you will need an adapter. You'll also need an adapter if your telescope has a 2-inch focuser but you would prefer using 1.25-inch eyepieces. Many telescopes come with adapters, but you can also purchase them separately.

When selecting an adapter, make sure that it is appropriate for the design. For example, hybrid star diagonals, which are designed to adapt 1.25-inch eyepieces into a sub-diameter 0.965-inch focuser, are only meant for refractors and cannot be used in reflectors. Also, be aware that adapters that fit 1.25-inch eyepieces into 0.965-inch focusers effectively add about a half inch of height to the focuser, which may raise the eyepiece enough to make focusing impossible.

Reticle Eyepieces

If you are thinking of taking astrophotos through your telescope, a reticle eyepiece is a "must have." Reticle eyepieces have internal grids, or reticles, superimposed over the fields of view. These grids come in a wide variety of designs, including those with two perpendicular lines that cross in the center and bull's-eye-style targets. Both designs are useful for guided astrophotography, along with micrometer scales designed for measuring object sizes and separations of double stars. Most reticles are illuminated with adjustable, red-light-emitting diodes (LEDs), powered by either internal batteries or external sources.

Finders

For amateur astronomers, there is nothing more frustrating than not being able to find an object through the telescope. That's why most instruments come with a finder for pointing. Finders come in two types: *finderscopes*, which magnify, and *unity finders* (also known as reflex finders), which do not.

Finderscopes are essentially low-power refractors that have the same specifications as binoculars. A 6x30 finderscope, for example, magnifies the view six times and has a 30mm aperture. Finderscopes usually come mounted to the telescope tube in a pair of adjustable rings. Some telescopes are sold with tiny 5x24 finderscopes, which are far too small and limited in capability to be of much use except for locating the moon and a few other bright objects. Even 6x30 finderscopes, supplied with many Dobsonians, are only marginally better. Most experienced observers agree that the smallest useful finderscope is an 8x50.

Unity finders do not magnify at all (or, more correctly, they magnify everything one time, hence the name "unity"). Some, like the Telrad, project bull's-eye targets onto pieces of flat glass that you aim toward the sky. Others project single red dots onto partially reflective curved windows. In both cases, the observer looks through the window to see the bull's eye or other marker floating against the stars.

Many observers prefer unity finders because they show exactly where a telescope is aimed against the entire sky. This makes aiming easier than using the restricted, usually inverted view you see through a finderscope. But unity finders show only the naked-eye sky. To locate a dim target, an observer must often star-hop among stars dimmer than naked-eye visibility (this is especially true in light-polluted areas). To get around this problem, many amateurs use both types of finders in unison, one supplementing the other.

Light-Pollution Reduction Filters

Light-Pollution Reduction (LPR) filters, sometimes called nebula filters, can go a long way toward reducing the damage done by runaway lighting. LPR filters come in three varieties: broadband, narrowband, and line filters. No one type is best for everything.

Broadband filters increase the contrast between a deep-sky object and the surrounding sky. But these filters are nearly worthless unless you are observing from inside a large city. Narrowband filters, on the other hand, can make a big difference in spotting emission and planetary nebulae from any observing site. It's important to note that narrowband and line LPR filters only work well on certain objects, such as emission nebulae and planetary nebulae. They do not improve the view of stars, star clusters, and galaxies.

Many owners of 10-inch and larger telescopes prefer using oxygen-III filters over narrowband filters, because the OIII filters usually reveal faint nebulae that remain invisible through other filters. Hydrogen-Beta line filters can also do an amazing job, but they work only on a few select objects, such as the Horsehead and California nebulae. On most other objects, Hydrogen-Beta filters actually make the view worse.

Moon and Planetary Filters

Color filters are designed to bring out fine details in the atmospheres and surfaces of the naked-eye planets and the moon by increasing subtle contrasts between two adjacent regions. They accomplish this task by allowing one color to pass through while absorbing (darkening) some or all other colors. Begin with a basic set of four — red, blue, green, and yellow — then expand your collection over time.

Moon filters are designed primarily to reduce the intensity of moonlight to comfortable levels, letting observers study the lunar surface in greater detail. A proper moon filter is neutral density; that is, it reduces all wavelengths of light (colors) evenly. Some moon filters will allow the user to vary the density, which can increase the versatility and allow the user to adjust the lunar glare to a comfortable level. These include variable density and variable polarizing filters. Some variable density filters don't work in all telescopes because they won't allow the eyepiece to be brought to a focus.

Solar Filters

Viewing the sun is a wonderful pastime that allows amateurs to follow the comings and goings of sunspots. But remember to be very careful when viewing the sun. You will need either to project the sun's image onto some sort of screen (which is not always recommended because it heats a telescope's optics) or to outfit your telescope with a solar filter that reduces the dangerously intense solar radiation to safe levels. Use only the type of solar filter that fits at the open end of the telescope. Solar filters that thread into an eyepiece are dangerous because the intense solar heat can cause them to crack. Solar filters are available in both glass and nonglass (usually metal-coated mylar) versions and can be custom fit to just about any telescope.

Hydrogen-alpha solar filters block all the sun's light except one distinctive wavelength: 656 nanometers. This is a particular wavelength of glowing hydrogen called hydrogen-alpha. Viewing the sun with an H-alpha filter allows the observer to monitor ruby red solar prominences, bright white filaments, and intricate surface granulation. Unfortunately, this fascinating view comes at a steep price, with H-alpha filters generally costing more than $1,000.

Collimation Tools

An owner of a reflector should make it a habit to check his or her telescope's optical alignment, or collimation, on a regular basis by using specially designed collimation tools. All reflector owners should have, at a minimum, a sight tube. Sight tubes include a set of crosshairs that help make sure all the optical components are properly centered. Cheshire eyepieces and autocollimators are designed primarily for fast Newtonian optics, where precise collimation is critical. Laser collimators make precise alignment easier to achieve, though if you are on a tight budget, they may be an unnecessary luxury.

Tip of the Iceberg

These devices are only the tip of the accessories iceberg. The tables also list many other items. All serve useful purposes, especially the antidew devices and observing chairs. This short list is by no means complete, but I hope it will serve to point you in the direction of some "must have" gadgets, while steering you away from other items you can live without. ■

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Company/ Focal Length	Barrel Diameter (inches)	Apparent Field of View (°)	Eye Relief (mm)	Price
ORTHOSCOPIC EYEPIECES				
Apogee, Inc.				
16.8	1.25	50	16	$25
10.5	1.25	50	10	$25
7	1.25	50	7	$25
Edmund Scientific				
25	1.25 or 0.965	47	22	$72
18	1.25 or 0.965	46	15	$72
12.5	1.25 or 0.965	44	10	$72
6	1.25 or 0.965	43	5	$72
4	1.25 or 0.965	41	3	$72
Pocono Mountain Optics				
25	1.25	45		$50
25	0.965			$42
18	1.25	45		$50
18	0.965			$42
12.5	1.25	45		$50
12	0.965			$42
9	1.25	45		$50
9	0.965			$42
7	1.25	45		$50
6	1.25	45		$50
6	0.965			$42
5	1.25	45		$50
5	0.965			$42
4	1.25	45		$50
University Optics				
25	1.25	47	23	$56
18	1.25	46	15.5	$56
12.5	1.25	45	10.5	$56
9	1.25	44	8	$56
7	1.25	44	6	$58
5	1.25	42	4	$58
4	1.25	41	3	$60
PLÖSSL EYEPIECES				
Adorama				
Pro-Optic 40	1.25	43	31	$40
Pro-Optic 32	1.25	50	22	$40
Pro-Optic 25	1.25	50	22	$30
Pro-Optic 20	1.25	50		$30
Pro-Optic 17	1.25	50	13	$30
Pro-Optic 12.5	1.25	50	8	$35
Pro-Optic 10	1.25	50	6.5	$30
Pro-Optic 7.5	1.25	50	5	$30
Pro-Optic 6.3	1.25	50	5	$35

Company/ Focal Length	Barrel Diameter (inches)	Apparent Field of View (°)	Eye Relief (mm)	Price
Apogee, Inc.				
40	1.25	40	33	$30
25	1.25	52	20	$30
20	1.25	52	18	$25
15	1.25	52	14	$25
10	1.25	52	11	$25
6.5	1.25	52	6	$25
5	1.25	52	5	$25
Celestron International				
40 (NexStar Plössl)	1.25	46	31	$55
32 (NexStar Plössl)	1.25	52	22	$55
25 (NexStar Plössl)	1.25	50	22	$45
17 (NexStar Plössl)	1.25	52	13	$45
13 (NexStar Plössl)	1.25	52	8	$45
10 (NexStar Plössl)	1.25	52	7	$45
8 (NexStar Plössl)	1.25	52	5	$45
6 (NexStar Plössl)	1.25	52	5	$45
3.6 (NexStar Plössl)	1.25	40	6	$45
Discovery Telescopes				
40	1.25			$45
30	1.25			$45
25	1.25			$45
20	1.25			$45
15	1.25			$45
12.5	1.25			$45
10	1.25			$45
6.5	1.25			$45
4	1.25			$45
Earth & Sky Products				
Spectiva 40	1.25			$44
Spectiva 25	1.25			$33
Spectiva 15	1.25			$33
Spectiva 10	1.25			$33
Spectiva 9	1.25			$33
Spectiva 6	1.25			$33
Hands-On Optics				
GTO-MC 40	1.25	46	31	$50
GTO 40	1.25	46	31	$40
GTO 30	1.25	49	22	$30
GTO-MC 25	1.25	50	22	$35
GTO 25	1.25	52	22	$25
GTO-MC 20	1.25	52	15	$35
GTO 20	1.25	52	15	$25
GTO-MC 17	1.25	52	13	$35
GTO-MC 12.5	1.25	52	8	$35
GTO 12.5	1.25	52	8	$25
GTO-MC 10	1.25	52	7	$35

Company/ Focal Length	Barrel Diameter (inches)	Apparent Field of View (°)	Eye Relief (mm)	Price
GTO 10	1.25	50	7	$25
GTO 9	1.25	50	7	$25
GTO-MC 7.5	1.25	52	5	$35
GTO 6.5	1.25	52	5	$25
GTO-MC 6.3	1.25	52	5	$35
GTO 4	1.25	52	4	$25
Meade Instruments				
40 (Series 3000)	1.25	44	29	$80
25 (Series 3000)	1.25	50	16	$60
16 (Series 3000)	1.25	50	10	$60
9.5 (Series 3000)	1.25	50	6	$60
6.7 (Series 3000)	1.25	50	4	$60
5 (Series 3000)	1.25	50	3	$60
56 (Series 4000 Super Plössl)	2	52	47	$190
40 (Series 4000 Super Plössl)	1.25	44	30	$100
32 (Series 4000 Super Plössl)	1.25	52	20	$100
26 (Series 4000 Super Plössl)	1.25	52	18	$80
20 (Series 4000 Super Plössl)	1.25	52	13	$80
15 (Series 4000 Super Plössl)	1.25	52	9	$80
12.4 (Series 4000 Super Plössl)	1.25	52	7	$80
9.7 (Series 4000 Super Plössl)	1.25	52	5	$80
6.4 (Series 4000 Super Plössl)	1.25	52	3	$80
Orion Telescope Center				
Sirius 40	1.25	43	22	$60
Sirius 32	1.25	50	25	$60
Sirius 26	1.25	50	18	$50
Sirius 26	0.965	50	16	$50
Sirius 20	1.25	50	14	$50
Sirius 20	0.965	50	13	$50
Sirius 17	1.25	50	13	$50
Sirius 17	0.965	50	10	$50
Sirius 12.5	1.25	50	7	$50
Sirius 12.5	0.965	50	8	$50
Sirius 10	1.25	50	7	$50
Sirius 10	0.965	50	5	$50
Sirius 7.5	1.25	50	5	$50
Sirius 7.5	0.965	50	4	$50
Sirius 6.3	1.25	50	5	$50
Sirius 6.3	0.965	50	5	$50
Parks Optical				
50	2	48	30	$140
35	1.25	45	25	$190
30	1.25	49	24	$150
25	1.25	52	16	$105
20	1.25	52	14	$105
15	1.25	52	12	$100
10	1.25	52	8	$100
7.5	1.25	52	6	$100
5	1.25	52	8	$150
3.8	1.25	52	6	$150
ScopeTronix				
40	1.25	44	30	$53
25	1.25	52	22	$43
15	1.25	52	14	$43
9	1.25	52	8	$43
6	1.25	52	5	$43
4	1.25	52	4	$43
Sky Instruments				
Antares 40	1.25	43	22	$75
Antares 32	1.25	50	25	$75
Antares 26	1.25	50	18	$75
Antares 20	1.25	52	14	$70
Antares 17	1.25	50	13	$75
Antares 15 (5-element)	1.25	52		$65
Antares 12.5	1.25	50	7	$75
Antares 10 (5-element)	1.25	52	7	$62
Antares 7.5 (5-element)	1.25	52	5	$65
Antares 6.3	1.25	50	5	$75
Omcon 40	1.25	43	31	$45
Omcon 32	1.25	52	22	$45
Omcon 25	1.25 or 0.965	52	22	$40
Omcon 20	1.25 or 0.965	52	15	$40
Omcon 17	1.25 or 0.965	52	13	$40
Omcon 12.5	1.25 or 0.965	52	8	$40
Omcon 10	1.25 or 0.965	52	7	$40
Omcon 7.5	1.25 or 0.965	52	5	$40
Tele Vue Optics				
55	2	50	38	$230
40	1.25	43	28	$110
32	1.25	50	22	$110
25	1.25	50	17	$95
20	1.25	50	14	$95
15	1.25	50	10	$85
11	1.25	50	8	$85
8	1.25	50	6	$85
BRANDON EYEPIECES				
VernonSCOPE				
48	2	50	44	$345
32	1.25	50	26	$235
24	1.25	50	19	$235
16	1.25	50	13	$235
12	1.25	50	10	$235
8	1.25	50	6	$235

BARLOW LENSES

Company/ Focal Length	Magnifying Factor	Barrel Diameter (inches)	Notable Features	Price
Adorama				
Pro-Optic Short Tube Barlow	2x	1.25	2.25" long	$32
Apogee, Inc.				
1.75x Barlow	1.75x	2	6" long; 46.5mm clear aperture	$75
2x Barlow	2x	1.25	2.5" long	$30
3x Barlow	3x	1.25	4.38" long	$40
Celestron International				
#93502 Deluxe Barlow	2x	0.965	Less than 3" long; fully multicoated optics; 21mm clear aperture	$45
#93507 Deluxe Barlow	2x	1.25	Less than 3" long; multicoated optics; 27mm clear aperture	$45
#93506 Ultima Apochromatic	2x	1.25	3-element optical design; 2.75" long; fully multicoated optics	$70
Earth and Sky Products				
Spectiva 2x Barlow	2x	1.25		$30
Edmund Scientific				
RKE	2.5x	1.25	Fully coated optics, 7" long	$99
Hands on Optics				
Short	2x	1.25	2.88" long; fully coated optics	$25
2x	2x	1.25	Fully coated optics	$32
Meade Instruments				
Model #134 Barlow	2x	0.965		$45
Model #122 Telenegative Barlow	2x	1.25	26mm clear aperture; multicoated optics	$50
Model #126 Short-Focus Barlow	2x	1.25	26mm clear aperture; 2.5" long; multicoated optics	$45
Model #127 Variable Barlow	2x – 3x	1.25	Engraved magnification scale; multicoated optics	$60
Model #140 Series 4000 Apochromatic Barlow	2x	1.25	3-element optical design; multicoated optics; 26mm clear aperture	$80
Orion Telescope Center				
#8740 Deluxe	2x	0.965	Multicoated optics	$37
#8746 Deluxe	2x	1.25	Multicoated optics	$48
#8710 / #8711 Shorty	2x	0.965 or 1.25	Fully coated optics; 2.88" long	$45
#8748 VariPower	2x – 3x	1.25	Fully multi-coated optics	$60
#8725 Ultrascopic	2x	1.25	3-element optical design; fully multicoated optics; 27mm clear aperture	$70
#8724	2x	2	Multicoated optics	$90
Pocono Mountain Optics				
Shorty	2x	1.25		$45
Deluxe	2x	1.25		$50
Deluxe	3x	1.25		$50
2"	2x	2		$145
Parks Optical				
701-30000	2x	0.965		$25
701-30010	2x	1.25		$60
701-30050	2x	1.25	Short	$80
701-30015	2x	2		$130
Sky Instruments				
Antares UB2S	2x	1.25	Short; multicoated optics; 29mm clear aperture	$60
Antares UB3S	3x	1.25	Short; multicoated optics; 27mm clear aperture	$70
Omcon B2S	2x	1.25	Short; fully coated optics	$30
Omcon B2T	2x	1.25	Short; fully coated optics; with T-thread adapter for astrophotography	$30
Tele Vue, Inc.				
2x	2x	1.25	Fully multicoated optics	$105
Big Barlow	2x	2	Fully multicoated optics	$170
2.5x Powermate	2.5x	1.25	4-element optical design; fully multicoated optics	$170
3x	3x	1.25	Fully multicoated optics	$105
4x Powermate	4x	2	4-element optical design; fully multicoated optics	$265
5x Powermate	5x	1.25	4-element optical design; fully multicoated optics	$170
University Optics				
Fully Baffled Barlow	2x	1.25	27mm aperture	$43
2" Barlow	2x	2	40mm aperture; multicoated optics	$90
Klee	2.8x	1.25	3-element optical design; multicoated optics; 2.5" long	$80
VernonSCOPE				
Dakin Barlow	2.4x	1.25	Multicoated optics	$185

Information in these tables was provided by manufacturers. In some columns, information is missing because it was unavailable at press time.

Company (Model/Diameter/Price)	Broadband (Model/Diameter/Price)	Narrowband (Model/Diameter/Price)	Oxygen-III (Model/Diameter/Price)	Hydrogen-beta (Model/Diameter/Price)
LIGHT-POLLUTION REDUCTION FILTERS				
Celestron International	LPR Filter #94126A, 1.25", $60 #94127A, fits back of SCT, $90	N/A	N/A	N/A
Lumicon	Deep Sky 1.25", $100 2", $200 SCT thread, $200	UHC 1.25", $100 2", $200 SCT thread, $200	Oxygen-III 1.25", $100 2", $200 SCT thread, $200	H-Beta 1.25", $100 2", $200 SCT thread, $200
Meade Instruments	Broadband #908B, 1.25", $80 #910B, 2", $120 #911B, fits back of SCT, $100	Narrowband #908N, 1.25", $90 #910N, 2", $120 #911N, fits back of SCT, $115	Oxygen-III #908X, 1.25", $100 #910X, 2", $150 #911X, fits back of SCT, $145	N/A
Orion Telescope Center	SkyGlow 0.965", $45 1.25", $60 2", $110 SCT thread, $90	UltraBlock 0.965", $80 1.25", $100 2", $140 SCT thread, $130	N/A	N/A
Parks Optical	LPB 1.25", $90 2", $140 SCT thread, $140	N/A	N/A	N/A
Sky Instruments	LPB Filter 1.25", $60 2", $100	N/A	N/A	N/A
Thousand Oaks Optical	LP-1 1.25", $90 2", $150	LP-2 1.25", $90 2", $180	LP-3 1.25", $90 2", $180	LP-4 1.25", $90 2", $180

Company/Model	Color Shades/ % Transmission	Diameter (inches)	Comments	Price
LUNAR AND PLANETARY FILTERS				
Adorama				
Pro-Optic Color filters	12 colors/shades	1.25	Standard thread; also available in sets	$10 each
Celestron International				
Color filters	12 colors/shades	1.25	Standard thread; 26mm clear aperture; also available in sets	$17 each
Moon filter	18% transmission	0.965 1.25	Standard thread; 21mm clear aperture (1.25"); 10mm clear aperture (0.965")	$17 $17
#93608 Variable Polarizing Filter	Varies between 5% and 30% transmission	1.25	Eyepiece fits into holder; may result in loss of correct focus in some telescopes with limited focuser travel	$45
Earth and Sky Products				
Moon filter		1.25	Standard thread	$10
Hands-on Optics				
GTO Moon filter	14% transmission	1.25	Standard thread	$10
Meade Instruments				
Series 4000 planetary filters	12 colors/shades	1.25	Standard thread; 26mm clear aperture; dyed-in-the-mass color	$18 each
Series 4000 Moon filter	13% transmission	1.25	Standard thread; 26mm clear aperture; dyed-in-the-mass color	$20
#905 Variable Polarizing Filter	Varies between 5% and 25% transmission	1.25	Eyepiece fits into holder; may result in loss of correct focus in some telescopes with limited focuser travel	$55
Orion Telescope Center				
Color filters	13 colors/shades	0.965 1.25 2	Standard thread; dyed-in-the-mass color; also available in discounted sets	$15 each $15 each $30 each
Moon filter	13% transmission	0.965 1.25	Standard thread; dyed-in-the-mass color	$16 $16
Variable polarizing filter	Varies between 3% and 40% transmission	0.965 1.25	Standard thread; two polarizing layers in rotating cell	$30 $40

Company/Model	Color Shades/ % Transmission	Diameter (inches)	Comments	Price
Parks Optical				
Color filters	14 colors/shades	1.25	Standard thread	$19 each
Moon filter	13%, 20%, or 50% transmission	1.25	Standard thread	$19
ScopeTronix				
Moon filter	14% transmission	1.25	Standard thread	$13
Sky Instruments				
Color filters	7 colors/shades	1.25	Standard thread; also available in sets	$13 each
Moon filter	13% or 20% transmission	1.25	Standard thread	$13
VernonSCOPE				
Color filters	13 colors/shades	1.25	Nonstandard thread*	$20 each
Polarizer	30% transmission	1.25	Nonstandard thread*	$20

* Note that VernonSCOPE filters are threaded to fit VernonSCOPE Brandon eyepieces only. An adapter to fit these filters to other, standard-thread eyepieces is sold separately.

Company/Model	Magnification	Aperture (millimeters)	Field of View (°)	Right Angle or Straight Through	Features	Price
FINDERSCOPES						
Apogee, Inc.						
50RA	8	50	6	RA	Interchangeable 1.25" eyepiece; mounting bracket sold separately	$100
50ST	8	50	6	ST	Interchangeable 1.25" eyepiece; mounting bracket sold separately	$50
70RA	12	70	4	RA	Interchangeable 1.25" eyepiece; mounting bracket sold separately	$200
Celestron International						
93779	6	30	7	ST	Mounting bracket sold separately	$35
93777	6	30	7	ST	Long eye relief; mounting bracket included	$50
93785-8P	7	50	5	ST	Illuminated Polaris finder reticle; mounting bracket included	$160
93783-8	9	50	5.8	ST	Mounting bracket included	$80
Coulter						
8x50	8	50	7	ST	Mounting bracket included	$90
8x50RA	8	50	7	RA	Mounting bracket included	$110
8x50ERA	8	50	7	RA	Mounting bracket included, 90-degree Amici prism; right-side-up field of view	$130
Discovery Telescopes						
5x24	5	24		ST	Mounting bracket included	$15
6x30	6	30		ST	Mounting bracket included	$36
7x50	7	50		ST	Mounting bracket included	$90
Earth and Sky Products						
Spectiva 6x30	6	30		ST	Mounting bracket included	$40
Lumicon						
50mm Super Finder	Eyepiece sold separately	50	Depends on eyepiece	ST, 45-deg, or RA	Mounting bracket and eyepiece sold separately	$70
80mm Super Finder	Eyepiece sold separately	80	Depends on eyepiece	ST	Mounting bracket sold separately; eyepiece sold separately	$200
80mm Super Finder	Eyepiece sold separately	80	Depends on eyepiece	RA	Mounting bracket included; eyepiece sold separately	$210
Meade Instruments						
#637	6	30	7	ST	Mounting bracket included	$50
#825	8	25	7.5	RA	90-degree finder for ETX	$50

Company/Model	Magnification	Aperture (millimeters)	Field of View (°)	Right Angle or Straight Through	Features	Price
#544 (blue)	8	50	5	ST	Mounting bracket sold separately	$70
#545 (white)						
Orion Telescope Center						
#13023	6	30	5.2	ST	Mounting bracket included	$40
#13000	6	26	6.3	ST	Mounting bracket included; erect image	$50
#13060	8	50	4.7	ST	Mounting bracket sold separately	$50
Roger W. Tuthill, Inc.						
50mm RA	7 or 8	50	Depends on eyepiece	RA	Dual Crosshair 1.25" diameter focusable eyepieces with rubber eyecups; Amici prism available separately	$200
80mm RA	11 or 15	80	Depends on eyepiece	RA	Dual Crosshair 1.25" diameter focusable eyepieces with rubber eyecups; Amici prism available separately	$320
ScopeTronix						
FS50	8	50		ST	Mounting bracket included	$65
Sky Instruments						
Omcon F30	6	30	n/s	ST	Mounting bracket included	$35
Antares F850	8	50	7	ST	Mounting bracket sold separately; translucent crosshairs	$70
Antares FR850	8	50	7	RA	Mounting bracket sold separately; translucent crosshairs	$90
Antares FE850	8	50	7	RA	Mounting bracket sold separately; 90-degree Amici prism; right-side-up field of view; translucent crosshairs	$100
Omcon F1050	10	50	n/s	ST	Mounting bracket sold separately	$55
Takahashi						
5x25	5	25		ST	Mounting bracket sold separately	$90
7x50	7	50		ST	Mounting bracket and illuminated reticle sold separately	$270
11x70	11	70		ST	Mounting bracket and illuminated reticle sold separately	$390
University Optics						
Right angle	8	50	4.2	RA	Interchangeable 1.25" eyepiece; right-angle prism	$125
Right angle Amici	8	50	4.2	RA	Interchangeable 1.25" eyepiece; 90-degree Amici prism; right-side-up field of view	$180
Vixen Optical Industries						
7x50 Achromatic	7	50	6.8	ST	Mounting bracket included	$190

Company/Model	Type (Target Or Dot)	Comments	Price
UNITY FINDERS			
Apogee, Inc.			
Mars-Eye	Dot	Dimmer; with mounting plate	$25
Celestron International			
Star-Pointer	Dot	Dimmer; with mounting plate	$35
Orion Telescope Center			
EZ Finder	Dot	With quick-release dovetail mount	$40
Rigel Systems			
QuikFinder	Target	Pulsing or steady 0.5- and 2-degree red circles; dimmer; includes two dovetail mounting plates	$40

Company/Model	Type (Target Or Dot)	Comments	Price
Scopetronix			
LightSight	Dot	Dual brightness setting	$25
Tele Vue			
Qwik-Point	Dot	Dimmer; with mounting plate; price varies with model	$20–$40
Starbeam	Dot	All-metal construction; dimmer; with mounting plate	$180
Telrad			
Telrad	Target	0.5-, 2-, and 4-degree red circles; dimmer; includes dovetail mounting plate	$40

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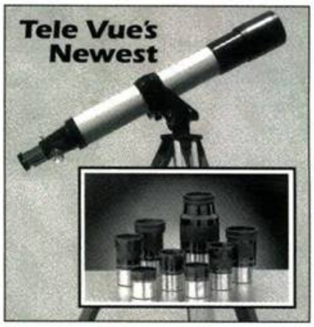

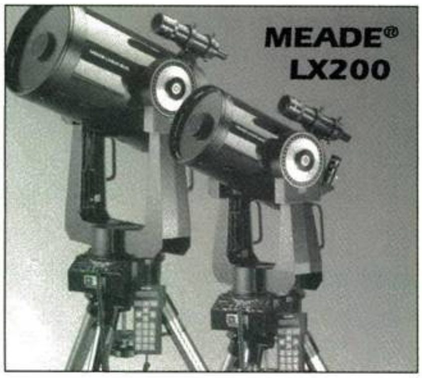

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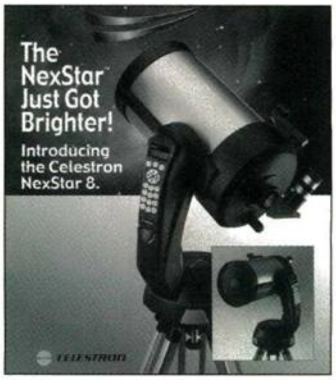

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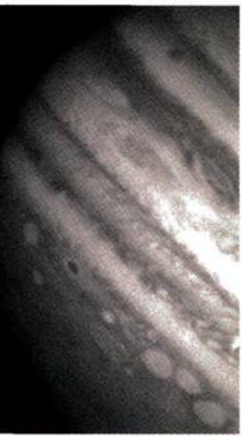

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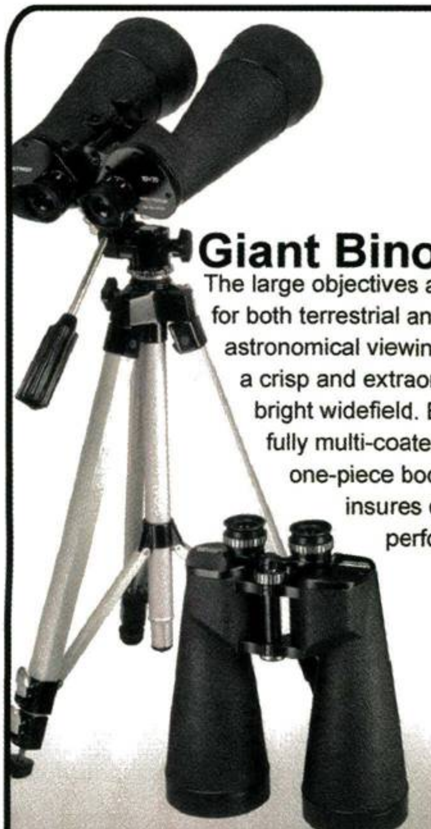

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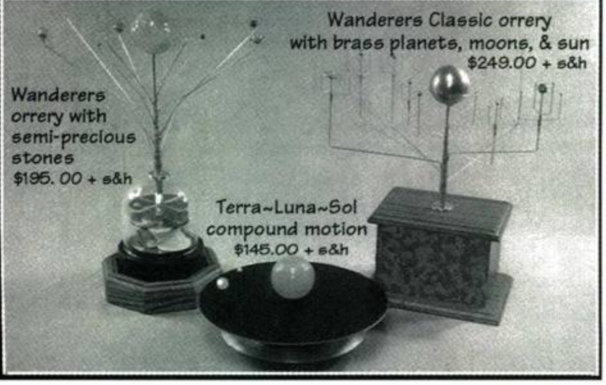
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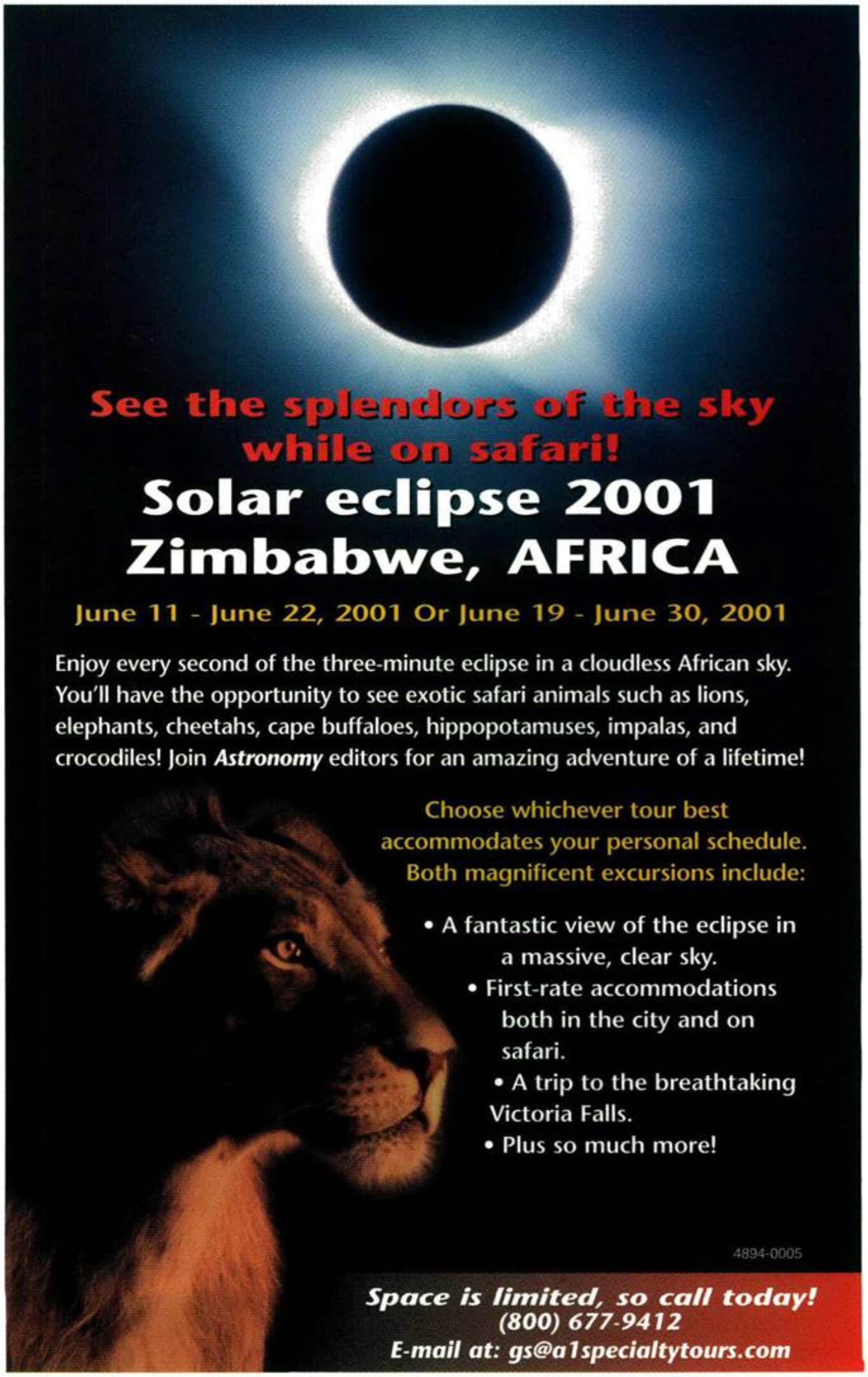

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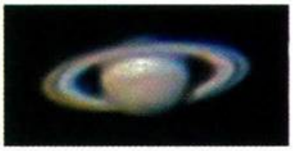

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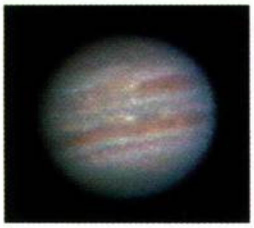

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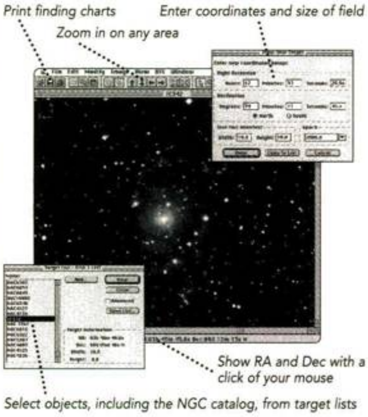
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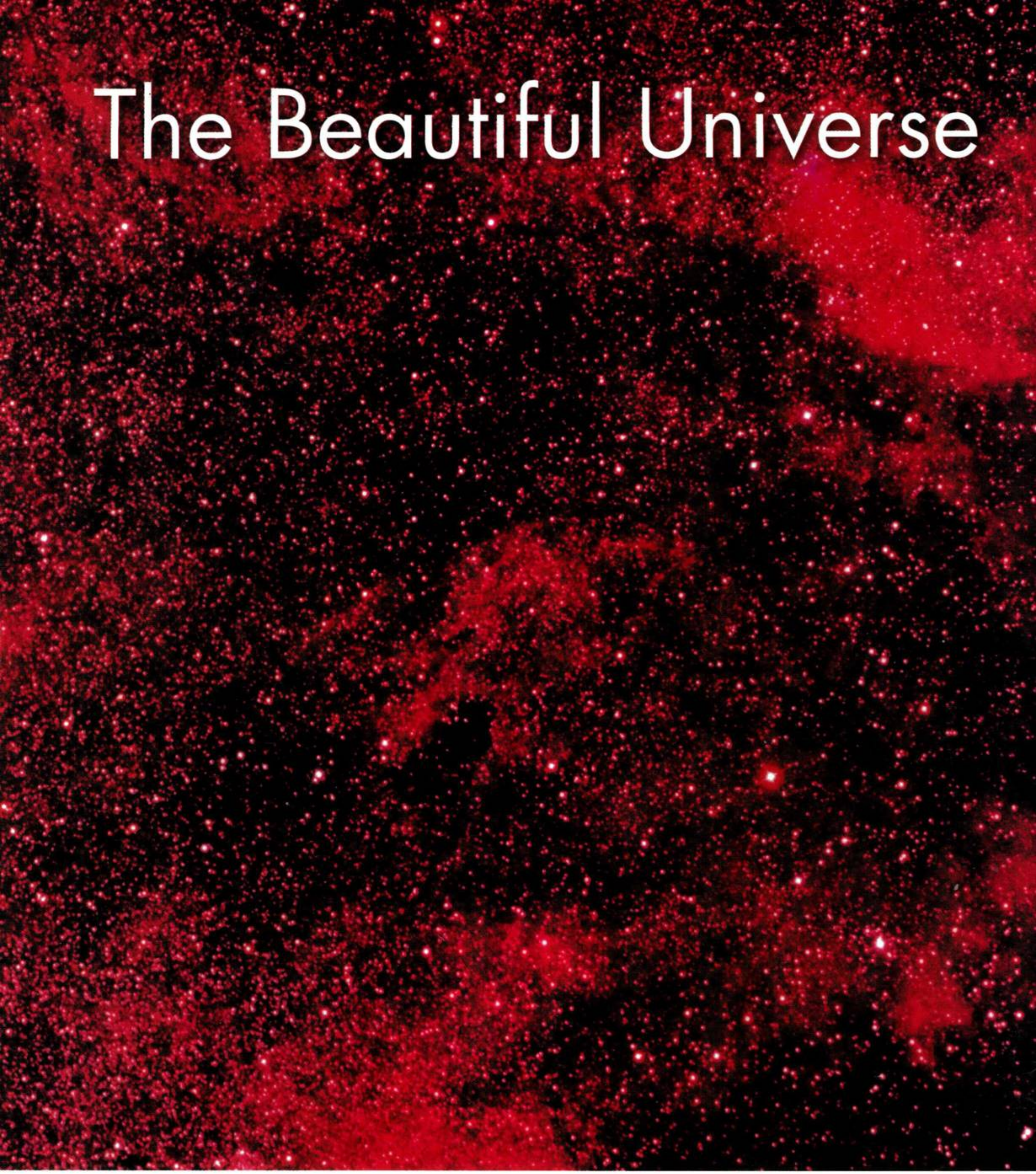
The Beautiful Universe

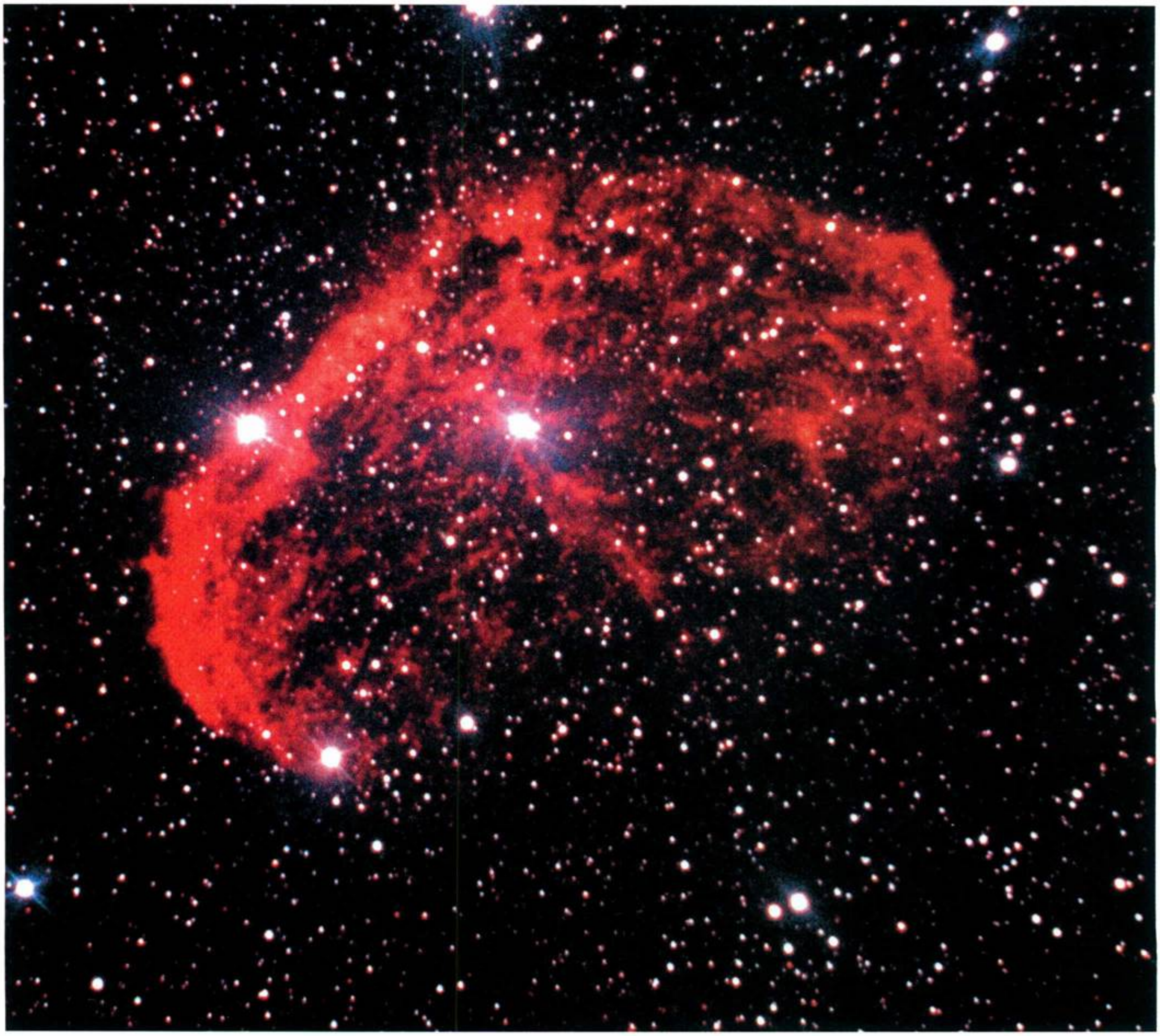


Gamma Cygni Region

JASON WARE

The region surrounding the star Gamma Cygni contains emission nebulosity such as IC 1318.
(12-inch SCT at f/2.2, Fuji HG 400 film, composite of two 7-minute exposures)

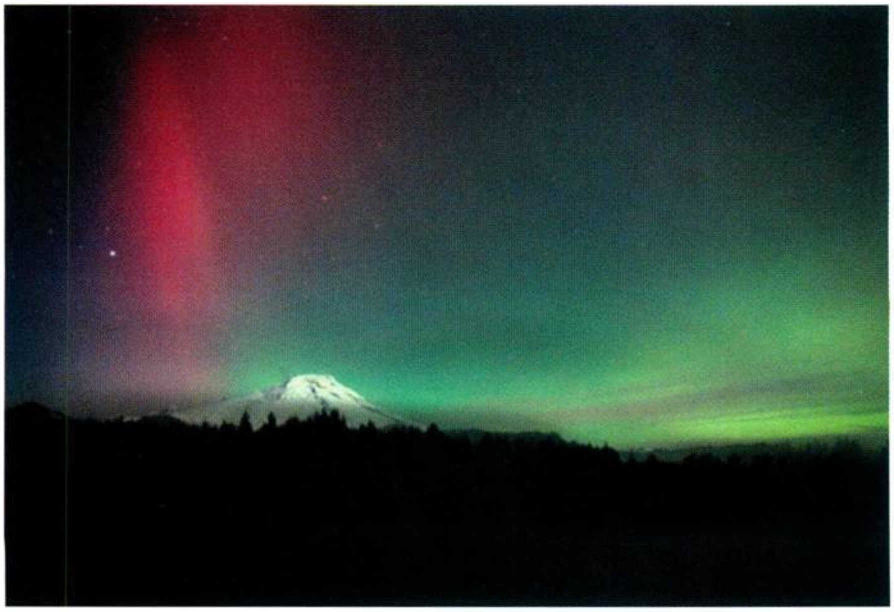
A gallery of some of the best photographs from the readers of *Astronomy*.



The Crescent Nebula

KEN BLANKENSHIP AND DENNIS BATIS

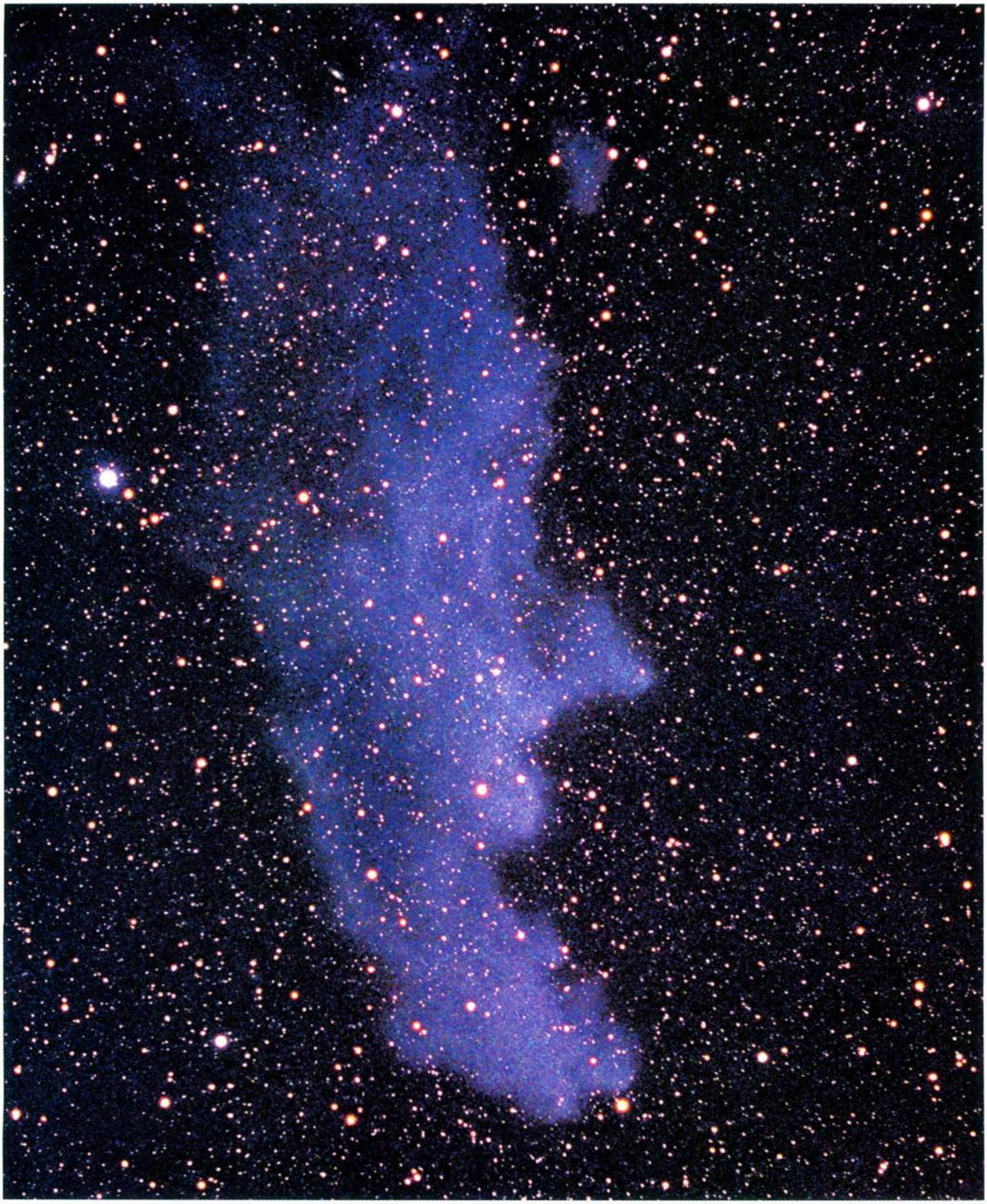
The Crescent Nebula, NGC 6888, is a challenging deep-sky object to find in the summer, centrally located in Cygnus. *(14-inch SCT at f/7.5, hypered Kodak PJ-400 film, Lumicon Skyfilter, 180-minute exposure)*



Northern Lights

WADE B. CLARK, JR.

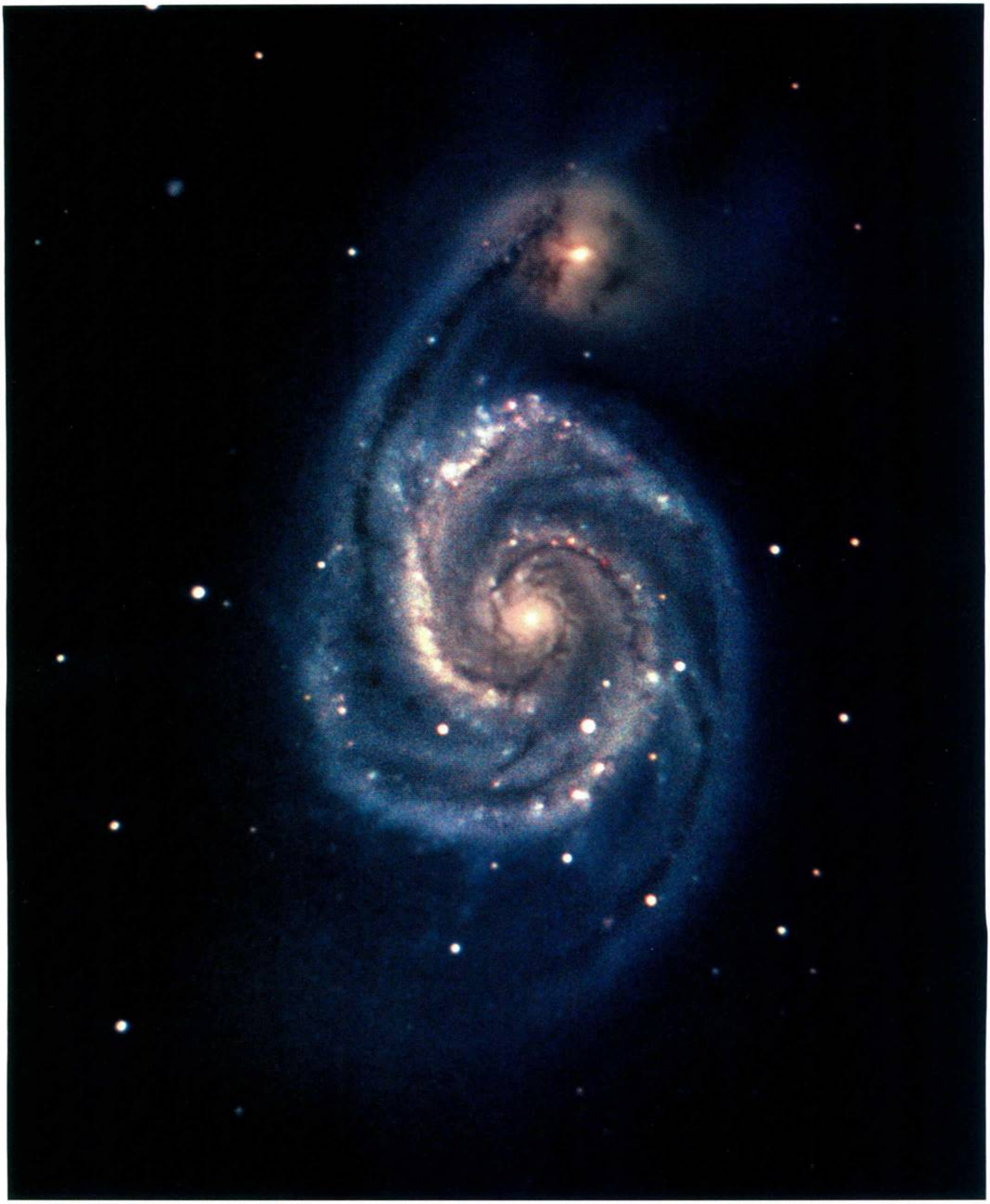
Red and green aurorae surge over a moonlit Mount Baker in Washington. *(28mm lens at f/1.8, Fuji Super G Plus 800 film, 50-second exposure taken November 7, 1998)*



The Witch Head Nebula

CHRIS COOK

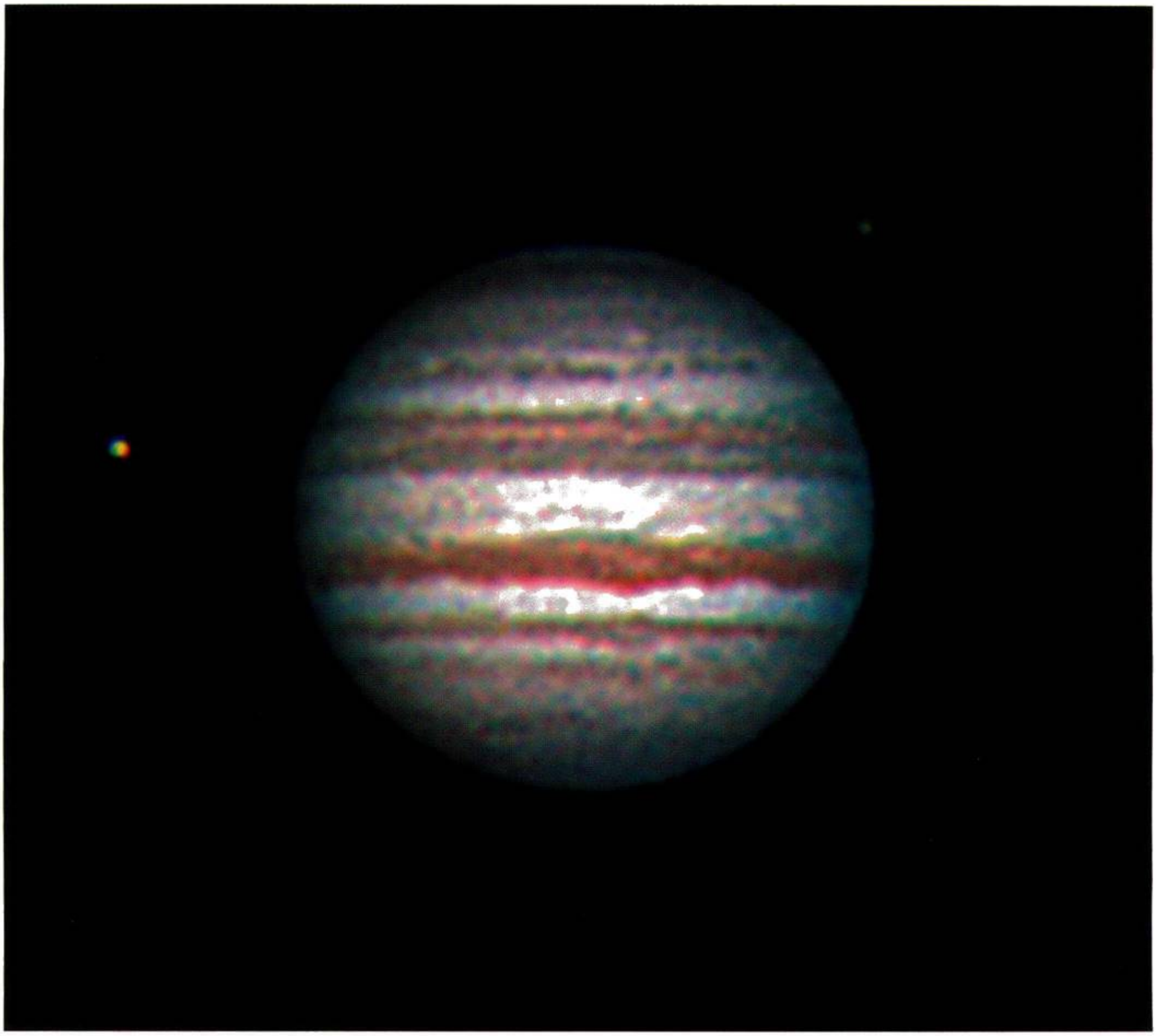
The Witch Head Nebula, IC 2118 in Eridanus, makes a popular and appropriate target for observing around Halloween. *(3.3-inch refractor at f/5.6, ST-4 CCD camera, hypered Kodak Ektapress PJ400 film, composite of three 40-minute exposures)*

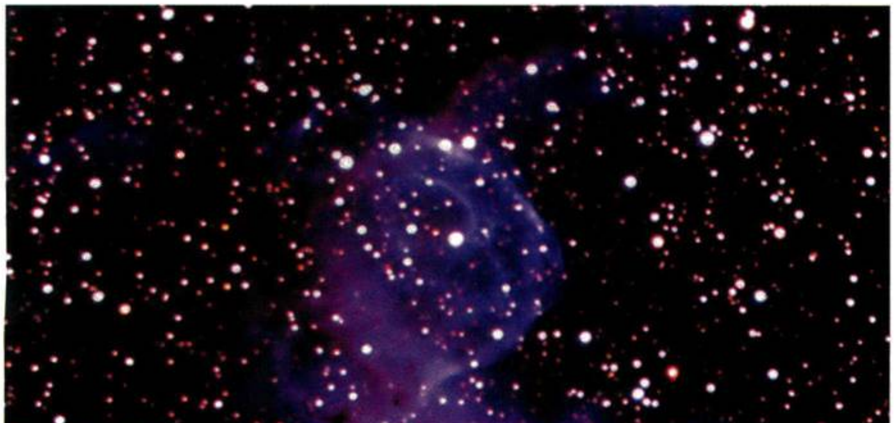


The Whirlpool Galaxy

JASON WARE

Lord Rosse was the first person to detect spiral structure in a galaxy — the Whirlpool Galaxy, M51, in the constellation Canes Venatici. *(16-inch SCT at f/10, hypered Fuji G800 film, composite of two 60-minute exposures)*





Jupiter with Europa and Io

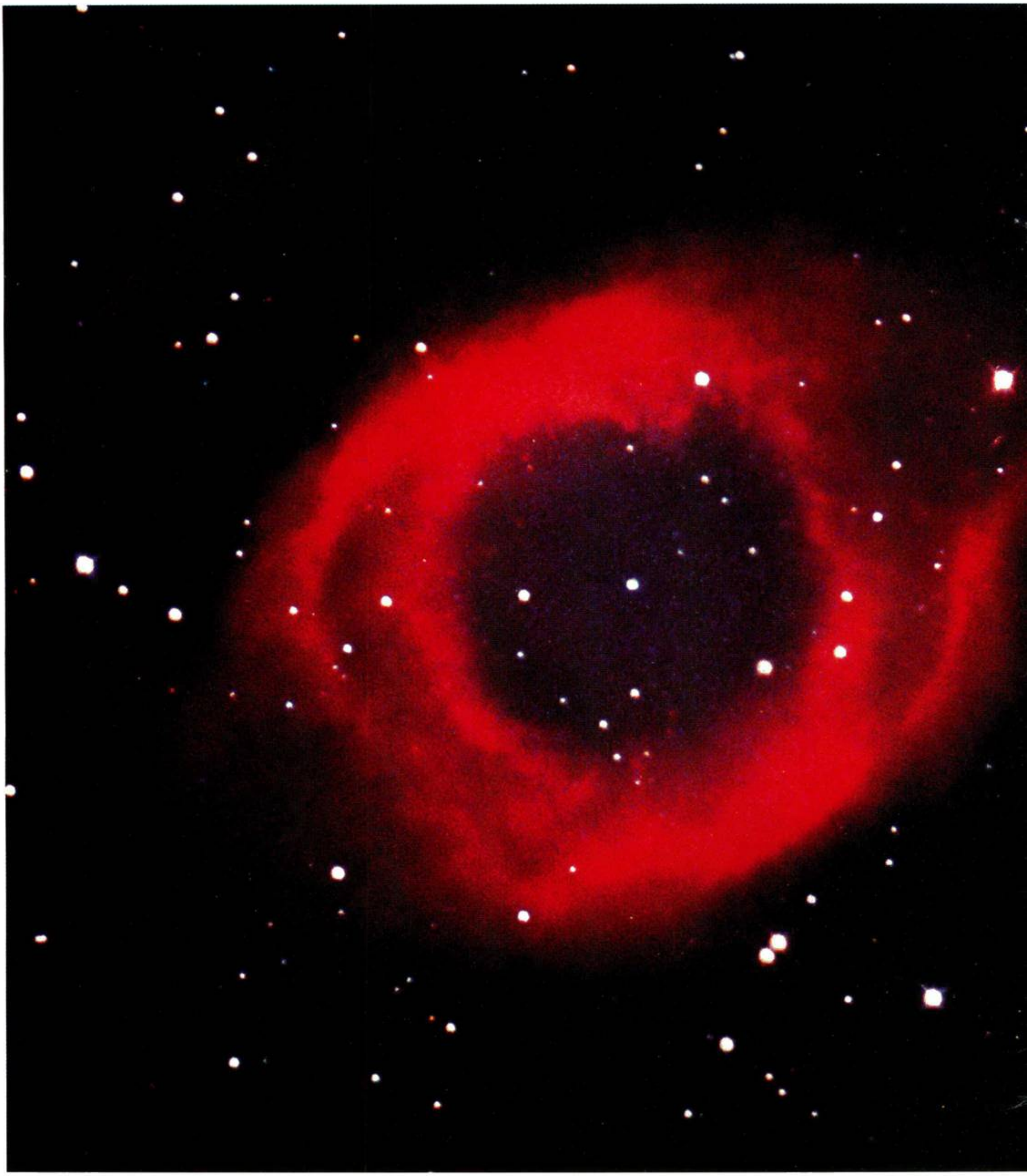
DAVID HANON

Even a modest telescope can reveal the atmospheric bands on Jupiter and its circling moons. *(7-inch refractor, ST-8 CCD camera, composite of 1-second red, 2-second green, and 3-second blue exposures taken August 23, 1999)*

NGC 2359 in Canis Major

JACK NEWTON

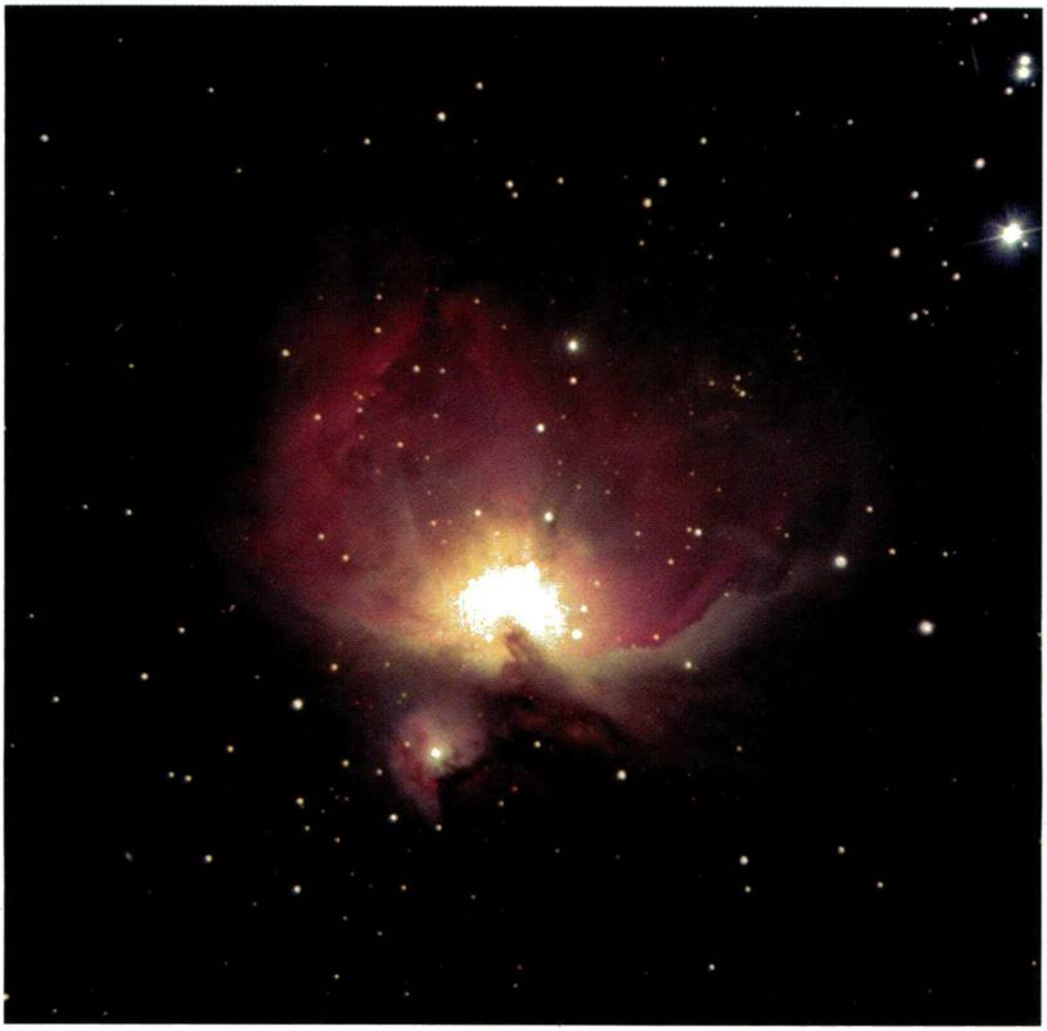
This is not the Bubble Nebula, but a bubble of nebulosity surrounding an extremely hot Wolf-Rayet star.
(16-inch SCT at f/6.3, 1616XTE CCD camera, composite of 10-minute red, 20-minute green, and 30-minute blue exposures)

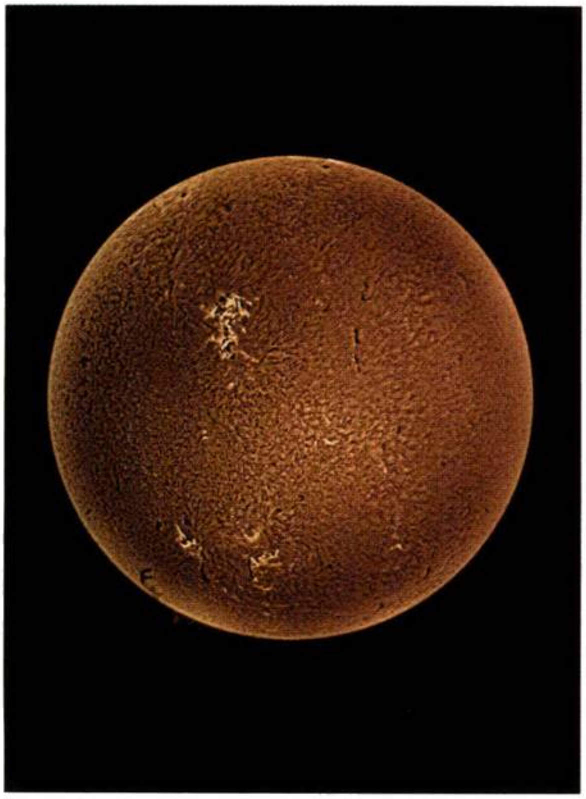


The Helix Nebula

GEORGE GREANEY

This planetary nebula in Aquarius, NGC 7293, is only 450 light-years from Earth, the closest known. *(14.5-inch Ritchey-Chrétien scope at f/8, hypered Kodak PPF Pro 400 film, composite of three 45-minute exposures)*





The Orion Nebula

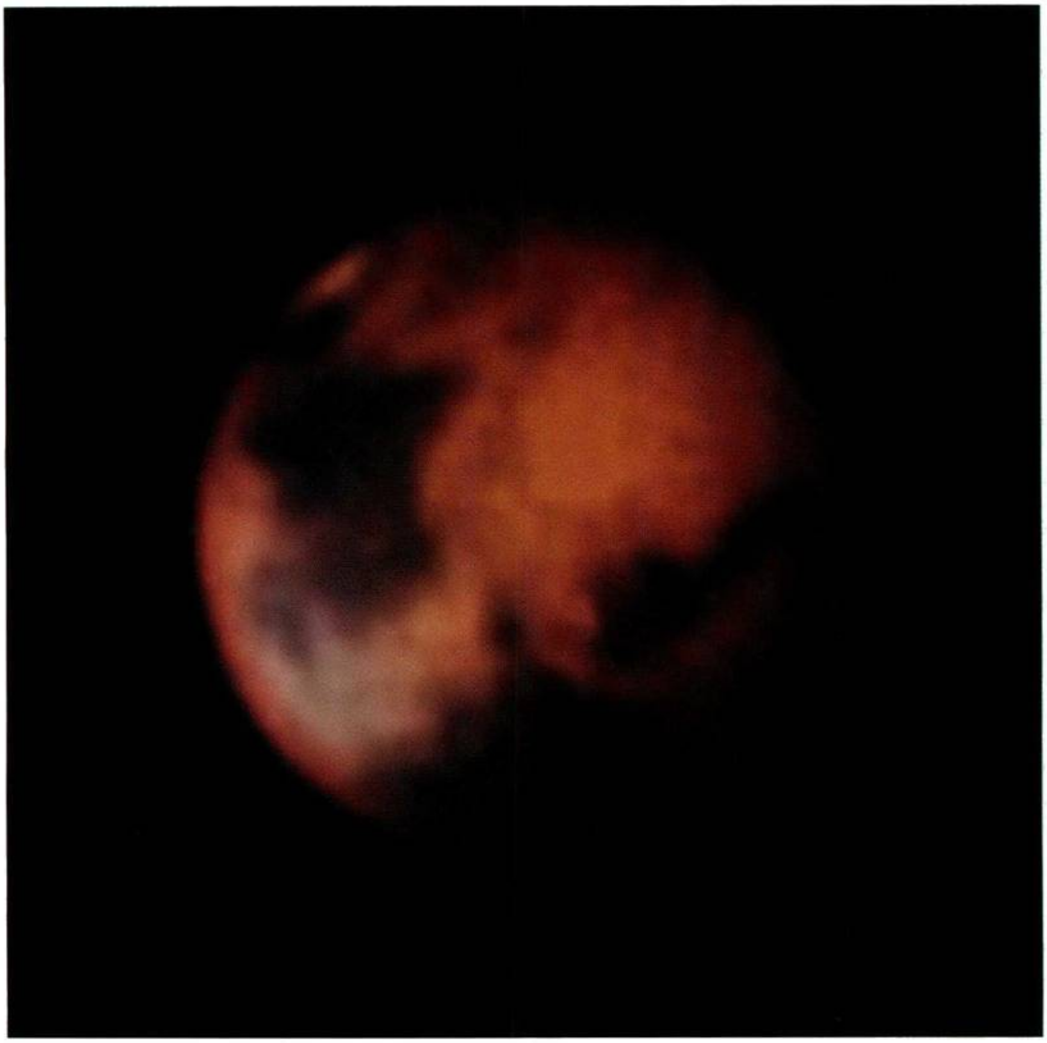
BARDON ZDENEK

The Orion Nebula, M42, is visible to the naked eye as a fuzzy patch in the sword of Orion.
(8-inch SCT at f/6.3, Fuji 400 film, 60-minute exposure)

Granulation on the Sun

ROBERT GENDLER

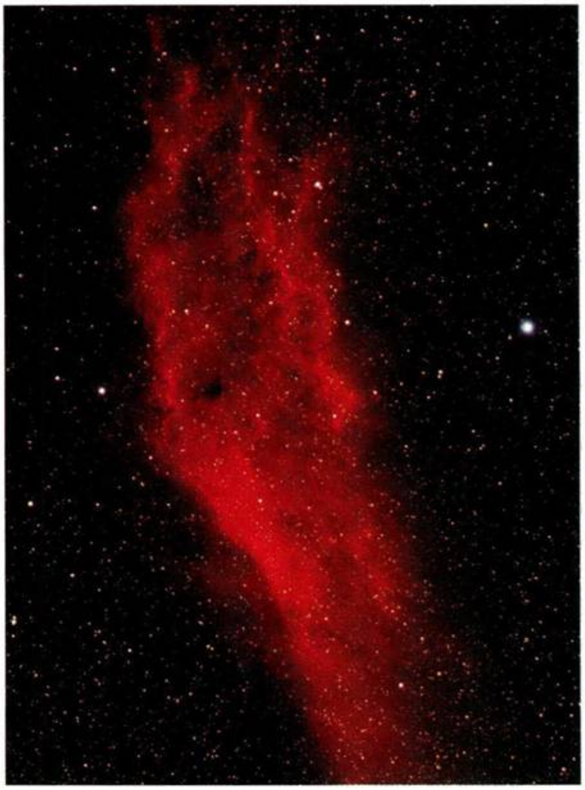
When viewed in hydrogen-alpha light, the sun's mottled surface resembles an orange.
(6-inch f/7 refractor, ST-8E CCD camera, Daystar 0.5A H-α filter, 1.5-second exposure)



Mottled Mars

JOHN CHUMACK

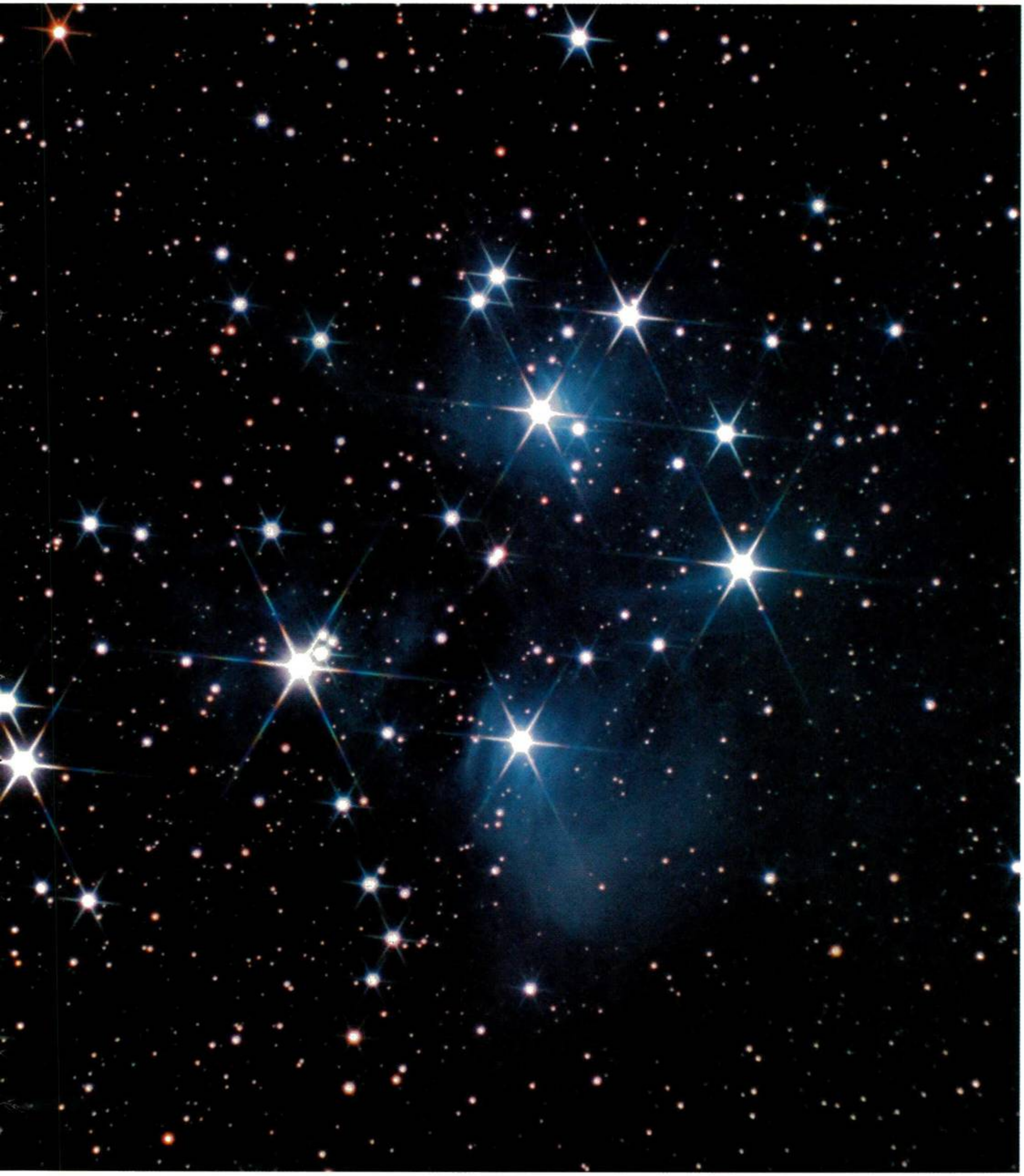
Mars put on a good display in 1999, answering the question of why we call it the Red Planet. *(10-inch SCT, ST-5 CCD camera)*



California Nebula

ALLEN HWANG

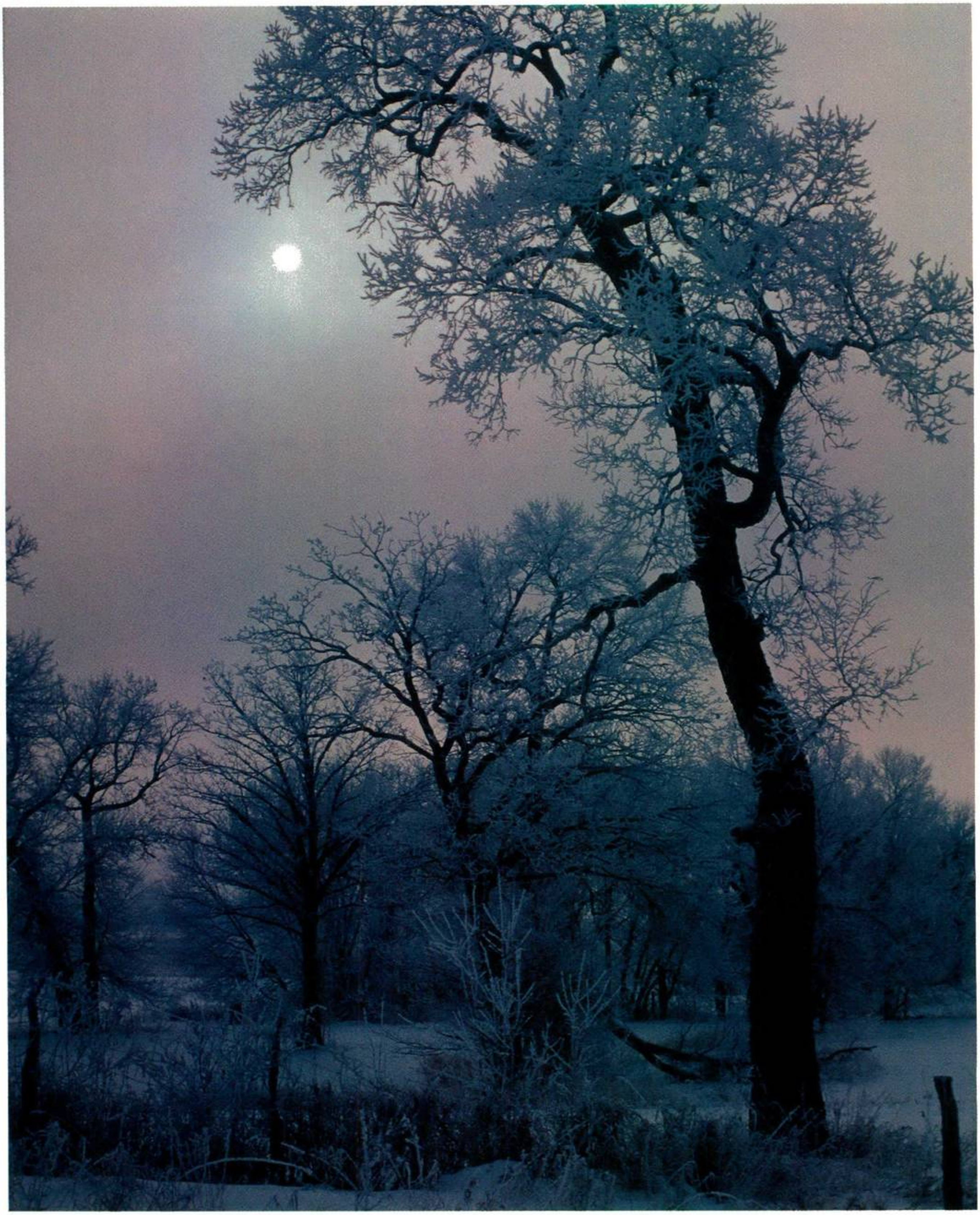
The California Nebula, NGC 1499 in Perseus, extends across 2.5° and glows by luminescence from the energy of Xi Persei. *(6-inch refractor at f/7, Kodak PPF 120 film, composite of two 60-minute exposures)*



The Pleiades

CONRAD POPE

The Pleiades star cluster, M45, is captured with the Merope Nebula and diffraction spikes. *(3.7-inch refractor at f/7, Kodak PJ 400 film, composite of three 40-minute exposures)*



Frozen Sun

RANDALL WEHLER

The sun's brilliance competes with Earth's atmosphere.
(50mm lens at f/16, Elite Chrome 100 film, 1/500-second exposure taken January 30, 2000)

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